Coastal and Hydraulics Laboratory

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First Powerhouse, Bonneville Dam, Columbia River, Oregon, Fish Guidance Efficiency System

Hydraulic Model Investigation

Robert Davidson

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Hydraulic Model Investigation

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Final report

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Preface

Experiments to evaluate potential fish guidance efficiency modifications for Bonneville First Powerhouse were performed for U.S. Army Engineer District, Portland (NPD). U.S. Army Engineer Research and Development Center (ERDC), formerly U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, received initial funding for this study September 7, 1995.

This study was conducted in the Coastal and Hydraulics Laboratory (CHL) ERDC, during the time frame January to June 1999 under the direction of Mr. Thomas W. Richardson, Acting Director, CHL; and Dr. P.G. Combs, Chief, Rivers and Structures Division, CHL.

Model velocity information as obtained and plotted by Mr. Robert A. Davidson, Mrs. Danea Polk, Messrs. Rudy Warnock, Tony Wooley, and Marshall Thomas under the direct supervision of Mr. Davidson. Analysis of the velocity information and final presentation of the information was accomplished by Mr. Davidson under the supervision of Mr. J.F. George, Chief, Fisheries and Structural Hydrodynamic Branch. This report was written by Mr. Davidson.

During the course of the model study, Messrs. Randy Lee and Mark Smith, NWP, and Messrs. Steve Rainy and Gary Fredricks, National Marine Fisheries Service, visited ERDC to observe model operation, review experiments results, and participate in experiment planning.

At the time of publication of this report, Director of ERDC was Dr. James R. Houston, and Commander and Executive Director was COL John W. Morris III, EN.

1 Model Study for Bonneville First Powerhouse Fish Guidance Efficiency System

Project Description

Bonneville dam is located on the Columbia River at river mile 146.1, approximately 40 miles east of Portland, OR (Figure 1). It is a multipurpose project that consists of the first and second powerhouses, the old and new navigation locks, and a 1,600,000-cfs capacity spillway. Construction of the first powerhouse, the old navigation lock, and spillway began in 1933. President Franklin D. Roosevelt dedicated the lock and dam on September 28, 1937. The construction of the First Powerhouse was completed in 1943. The First Powerhouse has a flow capacity of approximately 128,000 cfs and a rated power output of 526,700 kw. Construction of the second powerhouse began in 1974 and was completed in 1981. The second powerhouse has a flow capacity of approximately 160,000 cfs and a rated power output of 558,200 kw.

Background

The existing juvenile bypass system at the Bonneville First Powerhouse (BFP) is performing far below desired levels. To meet regional goals of providing survival of juvenile salmon at or above 80 percent, through nonturbine passage routes, it will be necessary to modify the existing bypass system. A 1-25-scale model was constructed at the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, to investigate these potential modifications. Items that were investigated in this model were: extended submerged bar screens (ESBS), streamlined trashracks (SLTR), alternate trashrack locations, and pier extensions.

Figure 1. Project location

Purpose

The main purpose of this study is to identify modifications to the BFP Fish Guidance System that will improve survival of juvenile salmon passing Bonneville Dam.

Similitude

Complete similitude in a laboratory model is attained when geometric, kinematic, and dynamic similitude is satisfied. Physical models of hydraulic structures with both internal flow (pressure flow) and external flow (free surface) typically are scaled using kinematic (Froudian) similitude at a large enough scale so that the viscous effects in the scaled model can be neglected. Velocities scaled using kinamatic similitude (model Froude number equal to prototype Froude number) in a 1:25-scale model have maximum Reynolds numbers at the peak discharge on the order of 10^5, yet the corresponding prototype values are on the order of 10^7.

Because the friction factor decreases with increasing Reynold's Number, the model is hydraulically too rough. The scaled friction losses in the model will be larger than those experienced by the prototype structure. This is standard practice.

Assumptions for model design

The following assumptions were made for designing the model.

a. The model would be operated between the upper limit of the 1-percent peak efficiency zone and the maximum turline output, which corresponds to a discharge of 11,300 and 14,700 cfs.

b. Experimental forebays would be within 71.5 and 76.5 ft.

c. The topography for the model would be designed by taking the average of the center-line topographies of units 1 to 6.

d. There is no need to actually have an operating turbine in the model to have representative flow lines through the intake.

e. The combination of 600 ft of approach with a good baffling will provide smooth flow into the intake structure.

f. Model would be designed without a lateral inflow component.

2 Model Description

A 1:25-scale model of one unit of the Bonneville First Powerhouse was constructed in 1995 (Figure 2 and 3). The model reproduced 700 ft of approach flume, all three bays of the intake structure, the scroll case, stays vanes, wicket gates, submerged traveling screens (STS) (Figure 4), vertical barrier screens (VBS) (Figure 5), and a portion of the ice and trash sluiceway. The model structure and approach flume were constructed from acrylic. The trashracks, STS, VBS, wicket gates, and stay vanes were constructed of brass. The U.S. Army Engineer District, Portland (NWP), supplied as built drawings of the Bonneville first structure and screens. Pertinent information needed for model design and construction were taken from these drawings and transferred into a Computer Aided Drafting program

Model Operation

Model conditions are set by introducing a desired discharge into the model and using a valve downstream of the wicket gates to establish the correct upper pool elevation. the wicket gates were set at full open for all experiments.

Model Calibration

Water is supplied to the model by three pumps. Each pump is capable of supplying 9,375 cfs (prototype). This provides a total inflow capacity of approximately 28,125 cfs (prototype) which far exceeds the discharge expected at the upper limit of the 1-percent peak efficiency zone or the maximum turbine output. A data industrial flow meter was placed in each inflow supply line to measure the inflow rate. Each flow meter was calibrated in the Volumetric Calibration Flume of the Coastal and Hydraulics Lab prior to installation. This is accomplished by introducing a desired flow into the calibration flume and timing the amount of time needed to fill a known volume. The flow rate is calculated by dividing the flume volume by the time required to fill the flume. This is repeated and the two values are averaged. This is the actual flow rate. During the above procedure the flow is measured by a data industrial flow meter. This procedure is repeated for several different inflows. Once this is completed, all actual flow rates are plotted against the data industrial measured values and a correction is applied to the data industrial flow meter to give the correct discharge value (Figures 6 through 8).

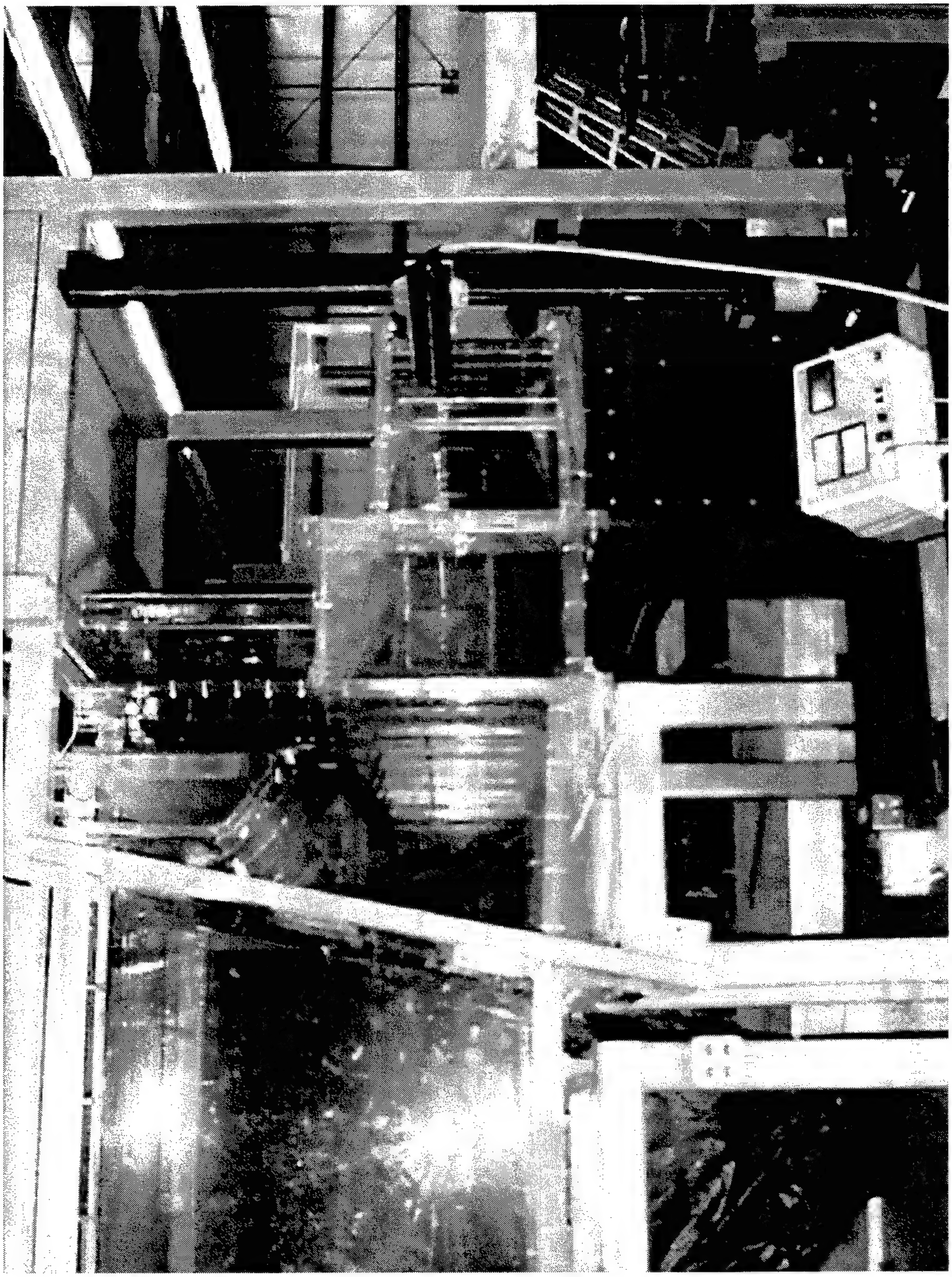


Figure 2. View of model intake structure

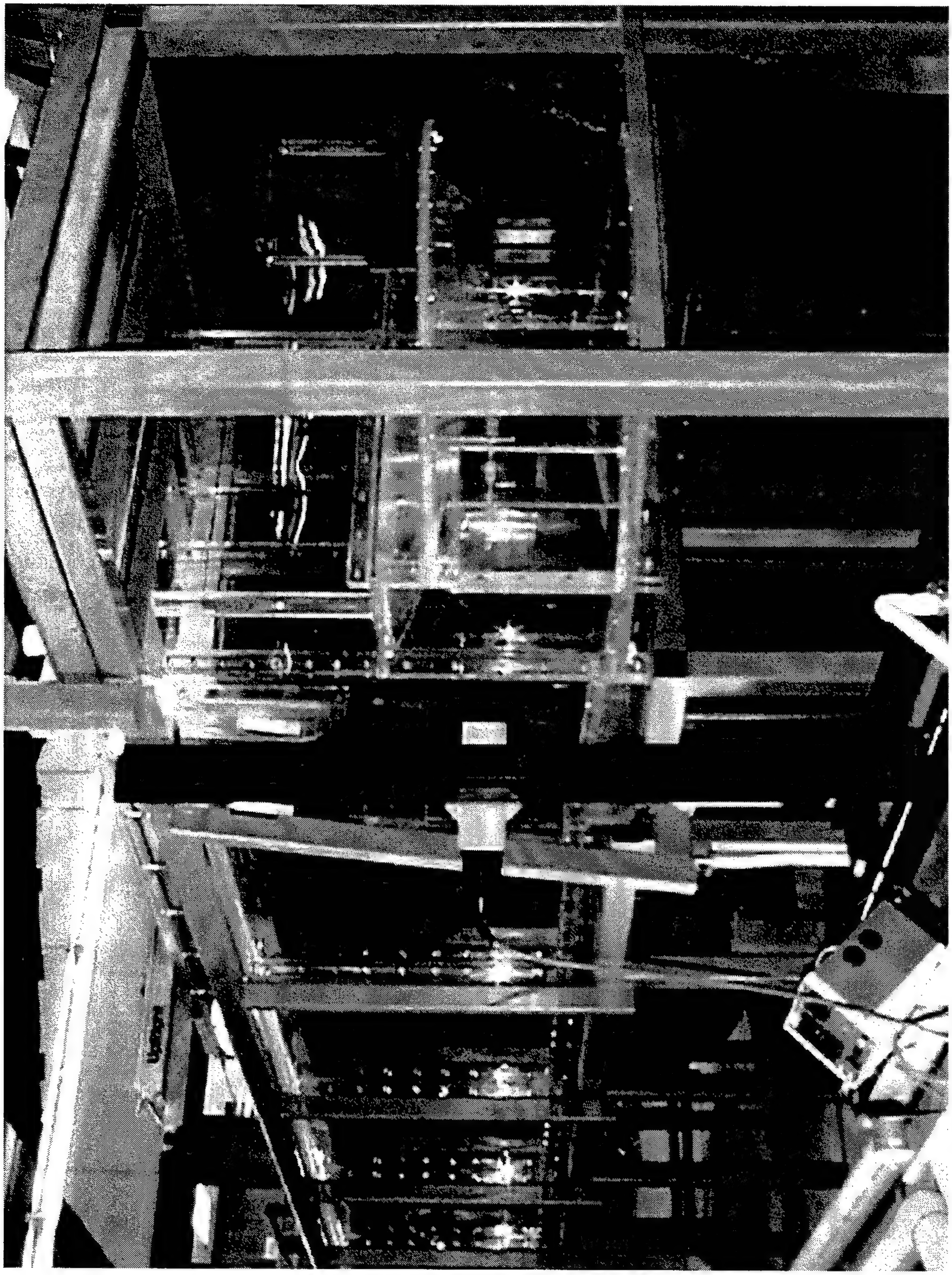


Figure 3. View of model looking upstream

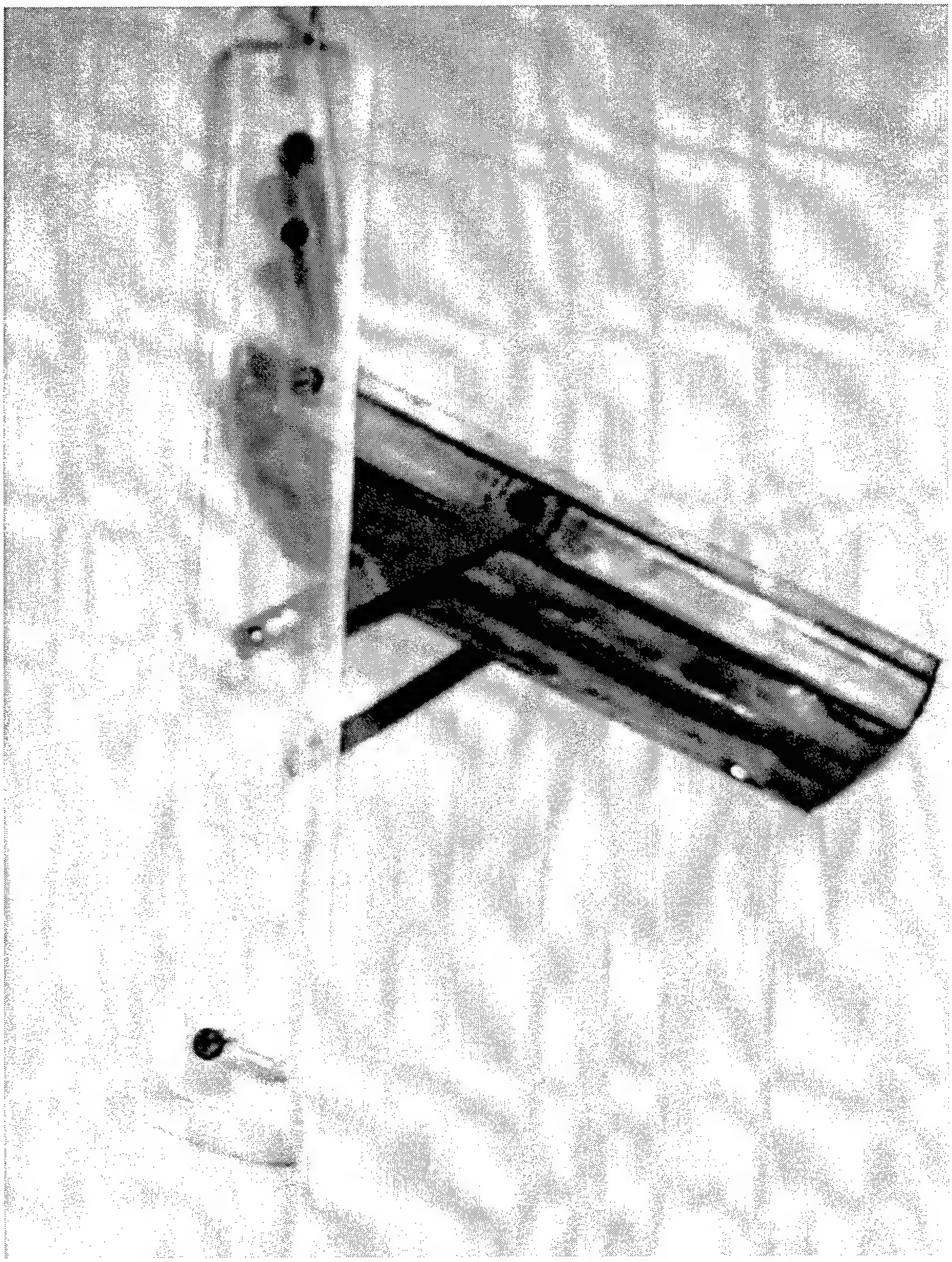


Figure 4. Model Submerged Traveling Screen (STS)

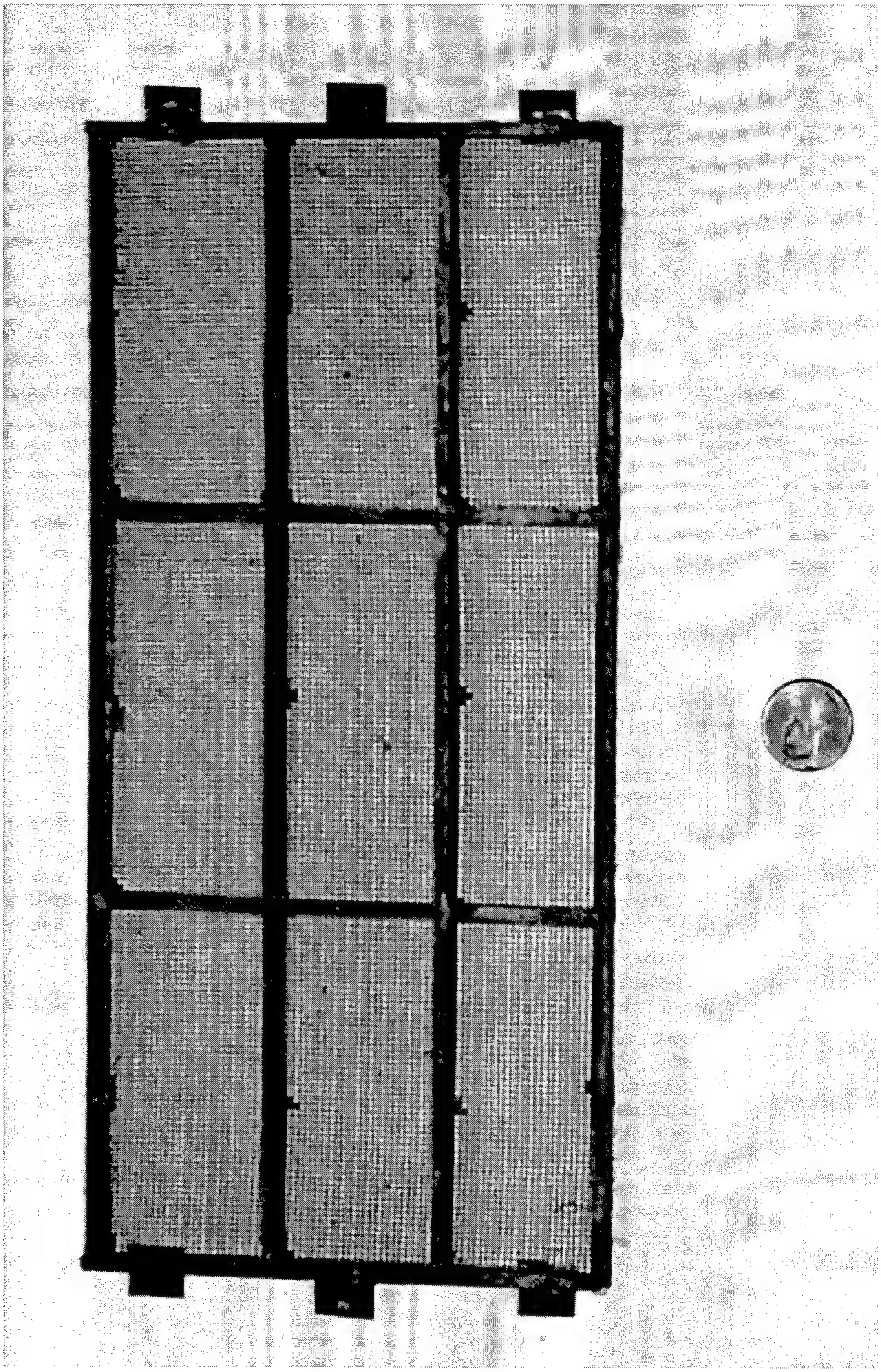


Figure 5. Model Vertical Barrier Screen (VBS) section

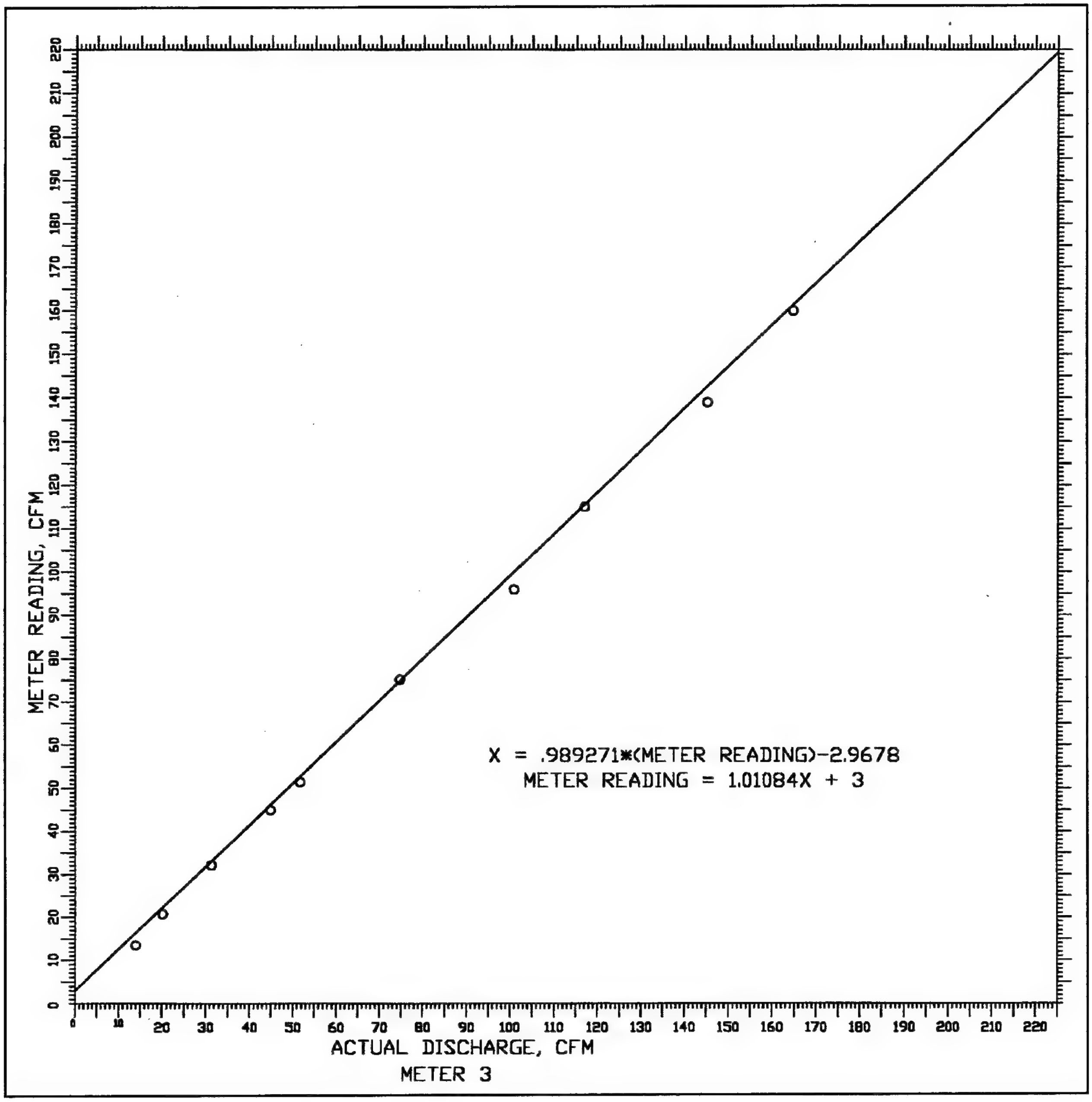


Figure 6. Flow calibration curve

LDV Calibration

All velocity information is obtained in the model with a Laser Doppler Velocity Meter (LDV). Calibration of this instrument is not required because it relies on the laws of physics. Known and exactly controlled frequencies of light are used in the measurement of the water velocity. These frequencies of light do not significantly change with temperature (water or air) or with the aging of the equipment. The accuracy of this instrument is better than 0.15 percent, which

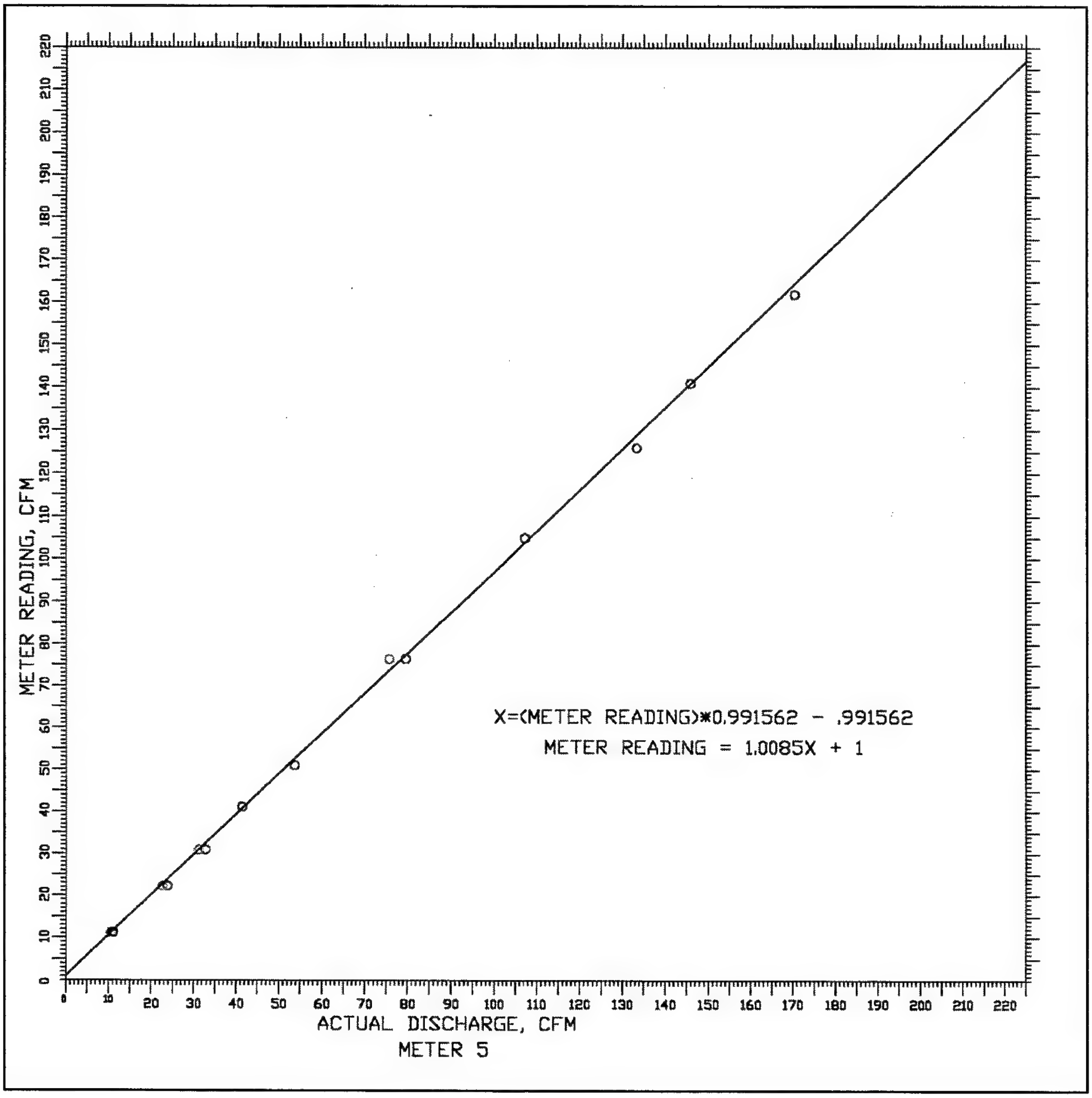


Figure 7. Flowmeter calibration curve

would yield an accuracy of plus or minus 0.01 ft/sec (prototype) at the upper velocity range expected for these experiments. This LDV system is also nonflow intrusive, which allows for measurement of the flow field without disturbance caused by the velocity meter. All measurements inside the intake structure will be obtained with this system.

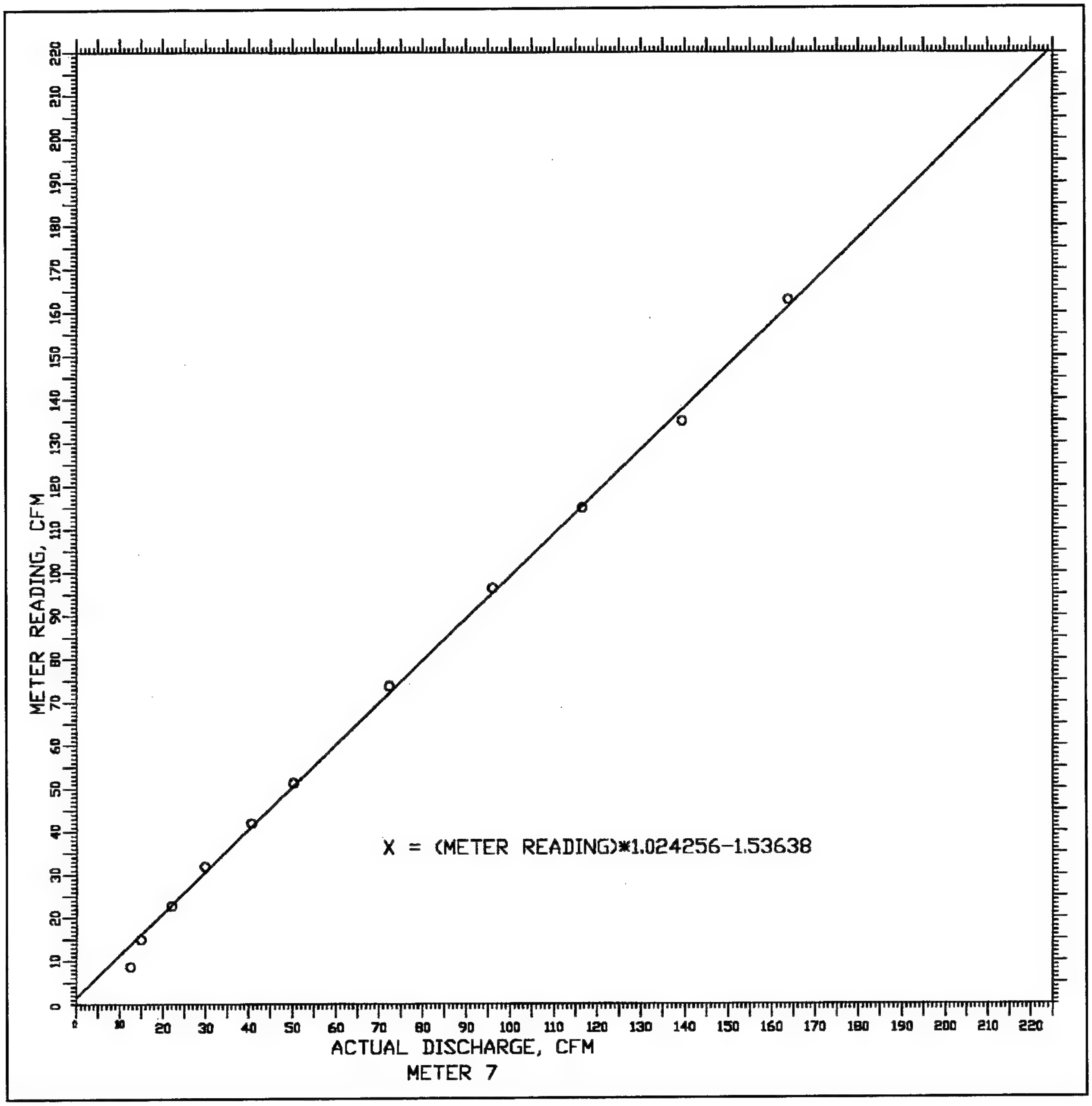


Figure 8. Flowmeter calibration curve

Comparisons of Inflow calibrated Meter with LDV Data

The first experiment performed in this model was a base test without screens installed. Velocities were measured in all three bays of the intake structure (Plates 1 through 3). Calculations of discharge through each bay was performed by assigning a control area for each measured velocity, calculating the flow in this area, and summing all measured velocities in a measured plane. The amount

of flow in bays A, B, and C was calculated to be 3,557 cfs, 3,785 cfs, and 4,060 cfs. Summing up the three bay discharges yields a total discharge of 11,402 cfs. The metered discharge was 11,650 cfs. This is a difference of 2.1 percent. This shows a close relationship between the inflow meter values and the LDV measured velocities.

3 Interpretation of Experimental Results

The accepted equations of hydraulic similitude, based on the Froudian relations, were used to express mathematical relations between the dimensions and hydraulic quantities of the model and the prototype. General relations for the transfer of model data to prototype equivalents, or vise versa, are presented in the following tabulation:

Dimension	Ratio	Model:Prototype Scale Relations
Length	Lr = L	1:25
Area	Ar = Lr^2	1:625
Velocity	Vr = Lr^.5	1:5
Time	Tr = Lr^.5	1:5
Discharge	Qr = Lr^2.5	1:3125

Original Fish Guidance Efficiency (FGE) Configuration

The existing FGE system (Figure 9) at the Bonnevillle consists of an STS installed in each of the three bays of the intake structure. These STSs are 20 ft long and are angled upstream at a 55-deg angle. Fish pass through the trashracks and are guided into a bulkhead slot, by the STS. Once in the gate slot, they are kept from passing back into the intake structure by the VBS. The VBS also keeps the juvenile fish in the vicinity of the orifice until they are able to find the orifice and pass into the bypass channel. The fish would then be transported downstream via a channel and released into the tailrace.

Experiments and Results

The second experiment conducted in this model was a base experiment to document flow conditions in the intake structure with the existing fish bypass configuration. Velocity information was obtained between the trashracks and STS, downstream of the STS, and along the VBS with the closure gate in place. Velocity information from this experiment can be seen in Plate 4. Flow intercepted by the STS was calculated from velocity data to be 22.3 percent.

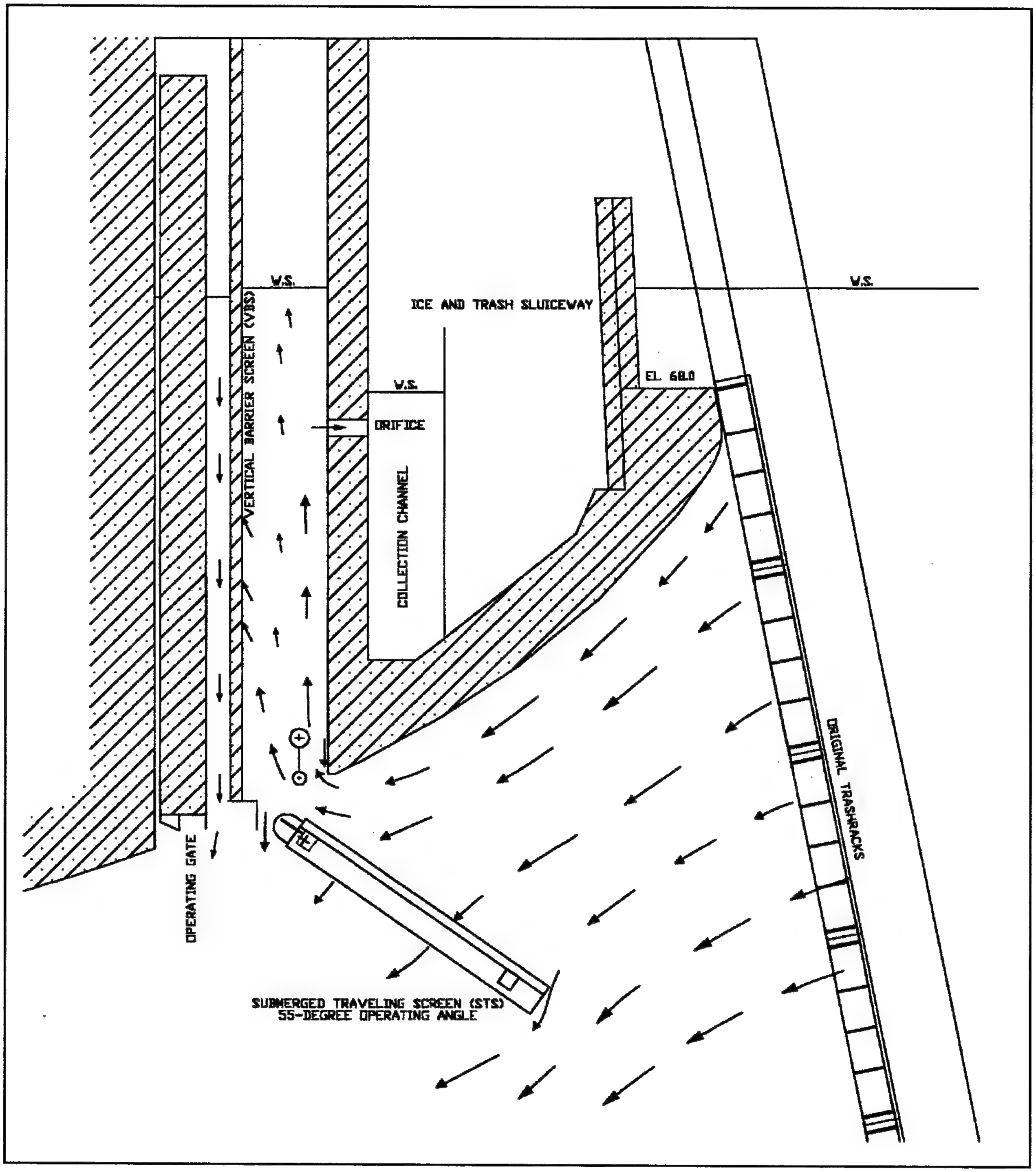


Figure 9. Original FGE configuration

From this data set, the influence of the horizontal structural support members of the trashracks on flow can be seen. The flow disturbance extends to the surface of the STS and has a high potential for affecting FGE and for disorienting fish. This indicates the trashracks should be redesigned.

4 Extended Submerged Bar Screen Experiments

ESBS Base Experiments

Experiments were conducted with an ESBS in place for turbine loading of 14,700 cfs with the original trashracks in place. The closure gate was removed for this experiment. The length of the ESBS was set at 40 ft based on information from other projects on the Columbia and Snake rivers that presently have operating 40-ft-long ESBSs. These data from this experiment are shown in Plate 5. The disturbances caused by the horizontal members of the trashrack are clearly shown in this plate. This experiment served as a base test for the ESBS design experiments.

ESBS Porosity Experiments

Experiments were performed to determine the optimum porosity of the ESBS. The porosity plate is attached to the downstream side of the ESBS and controls the amount of flow that passes through the screen as well as the amount of flow that is intercepted by the bypass system. The greater the amount of flow intercepted by the screening device, the greater the potential for guiding fish. However, the greater the quantity of flow passing through the ESBS the higher the velocity is along the screen face. Based on experiments conducted in a 1:25-scale McNary model and prototype biological experiments, the acceptable maximum (perpendicular component) velocity at the screen face is 2.75 ft/sec. These are the criteria that were used for the ESBS design experiments.

Velocity information was obtained along the ESBS screen face and between the ESBS and trashracks slot for turbine loadings of 14,700 and 11,200 cfs. These discharges represented the high discharge that could occur at the project and the high discharge side of the 1-percent efficiency zone, respectively. Since the existing trashracks cause disturbances that extend to the screen surface, they should be redesigned. It was assumed that the redesigned trashracks would be nearly invisible to the flow field at the screen face and due to a tight prototype construction were removed from the model for all porosity plate experiments. The redesign of the trashrack will be addressed later in this report. Porosity plates of 48, 40, and 30 percent were used for the turbine loading of 14,700 cfs,

and porosity plates of 48 and 30 percent were used for the lower discharge of 11,000 cfs. Velocity information from these experiments can be seen in Plates 6 through 23. Graphs comparing the porosity of the screen to intercepted flow, perpendicular flow through the ESBS as well as the parallel component of flow along the screen, are provided in Plates 24 through 26. At the high discharge of 14,700 cfs, the 48-percent porosity plate arrangement intercepted the most flow (51 percent), and the perpendicular velocity component is 2.6 ft/sec which is below the 2.75 ft/sec value. For this reason, the 48-percent porosity plate was chosen as the recommended porosity and all future ESBS experiments were performed with this plate in place.

ESBS Elevation Experiments

Previous ESBS experiments were conducted with the screen pivot point elevation (el) set at elevation 37.5 ft.[1] Experiments were conducted with the screen in two different lowered positions at a turbine loading of 14,700 cfs. In the first experiment, the screen was lowered 1 ft (el 36.5 ft) and velocity information was obtained between the trashrack and ESBS and in the bulkhead slots (Plates 27 and 28). The percent flow intercept was calculated as 50.6 percent which is nearly the same as with the ESBS in it's normal elevation. The gate slot discharge was calculated from measured velocity information and was 375 cfs. The gate slot discharge for the ESBS for the screen in its normal position was calculated to be 362 cfs.

The second screen lowering experiment was conducted with the screen lowered 2 ft (el 35.5 ft). Velocity information (Plates 29 and 30) was obtained upstream of the ESBS and in the bullhead slots. The percent flow intercepted by the screen was calculated as 52.7 cfs and the gate discharge was 406 cfs. This shows a benefit both in gate slot flow and the amount of flow intercepted over both the normal and 1-ft lower screen positions.

[1] All elevations (el) cited herein are in meters referenced to the National Geodetic Vertical Datum.

5 Inlet Flow Vane Experiments

Flow separation occurs as flow passes through the screen throat area and enters the screen slot. This flow separation causes unstable flow to be concentrated along the face of the VBS. This is a potential problem for fish to pass safely in the vicinity of the VBS. Also this flow separation reduces the efficiency of the throat area and reduces the amount of flow that passes into the screen slot. This flow is important for attracting juvenile salmon. A flow vane is a device that would be placed in the throat area of the screen slot. Its purpose is to streamline flow into the screen slot, eliminate the flow separation that occurs at this point, and to distribute the flow more evenly across the width of the slot.

Detailed velocity information was obtained in the throat area of the screen slot and upstream of the ESBS tip with the ESBS at three different elevations for a turbine loading of 14,700 cfs. These three experiments served as a base for design of the flow vanes. Velocity information from these three experiments is provided in Plates 28, 29, and 31.

Experiments were conducted on two flow vanes. Schematics for these two flow vanes can be seen in Figures 10 and 11. The major difference in these two designs is the radius of the lower portion of the flow vanes. These experiments consisted of obtaining data in the screen slot throat area and between the ESBS and the trashrack slot.

Velocity information was obtained upstream of the ESBS and in the throat area of the screen slot with the ESBS in a 2-ft lowered position. Vane 1 was positioned above the top of the ESBS. Velocity information obtained for this experiment can be seen in Plates 32 and 33. The flow intercepted by the ESBS was calculated as 51.4 percent, which is closely related to the same model setup without Vane 1 in place (52.7 percent). The flow up the screen slot was calculated to 526 cfs. This is a significant increase in gate slot flow when compared to the same model setup without Vane 1 in place (406 cfs).

Vane 1 was removed and replaced with Vane 2. The experiment was repeated and the amount of flow intercepted by the screening device was calculated to be 52 percent and the amount of flow directed up the screen slot was 571 cfs. This screen slot discharge was greater than the screen slot discharge with Vane 1 in place (526 cfs), but the amount of flow intercepted by the

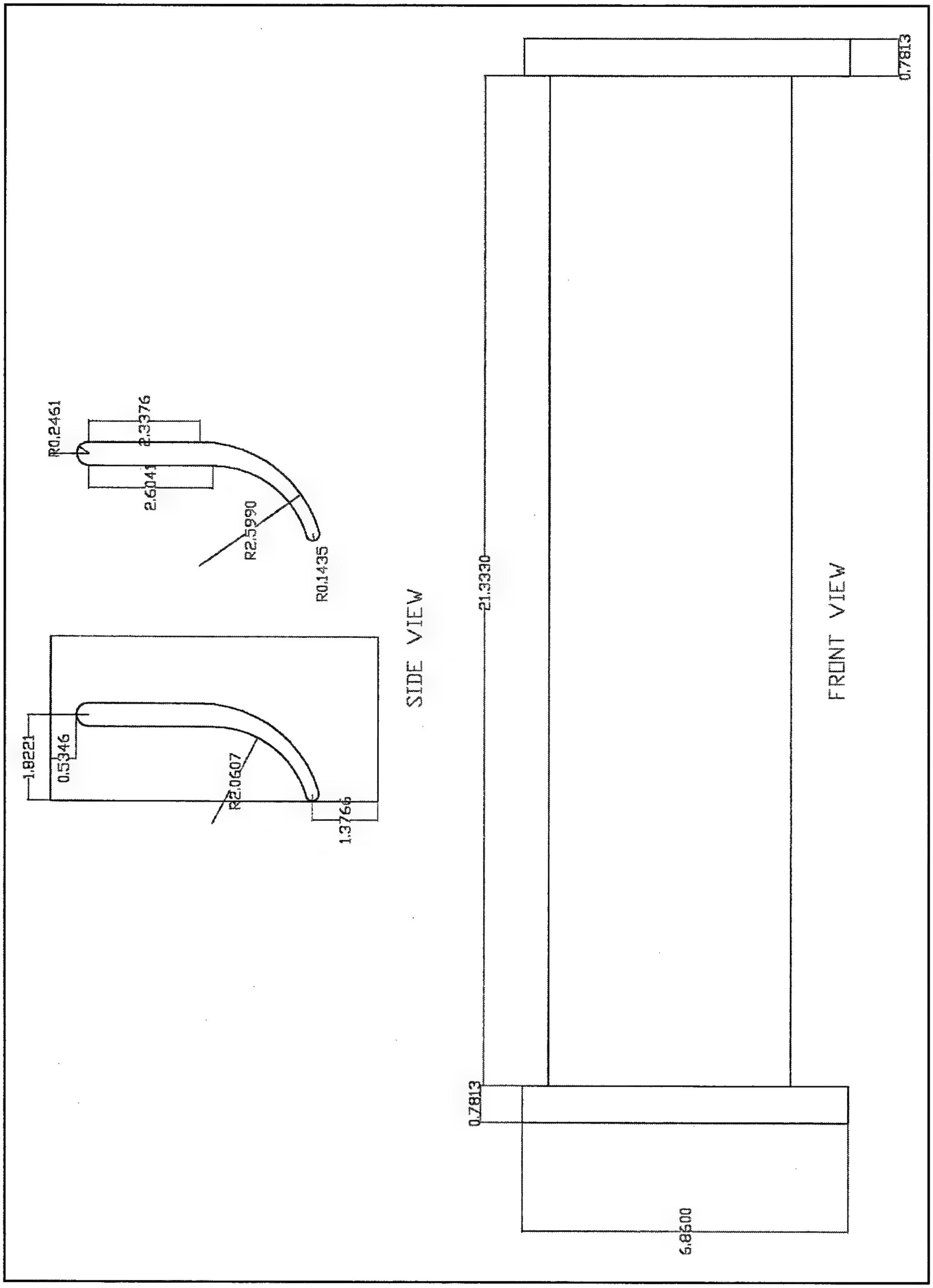


Figure 10. Vaning device number 1

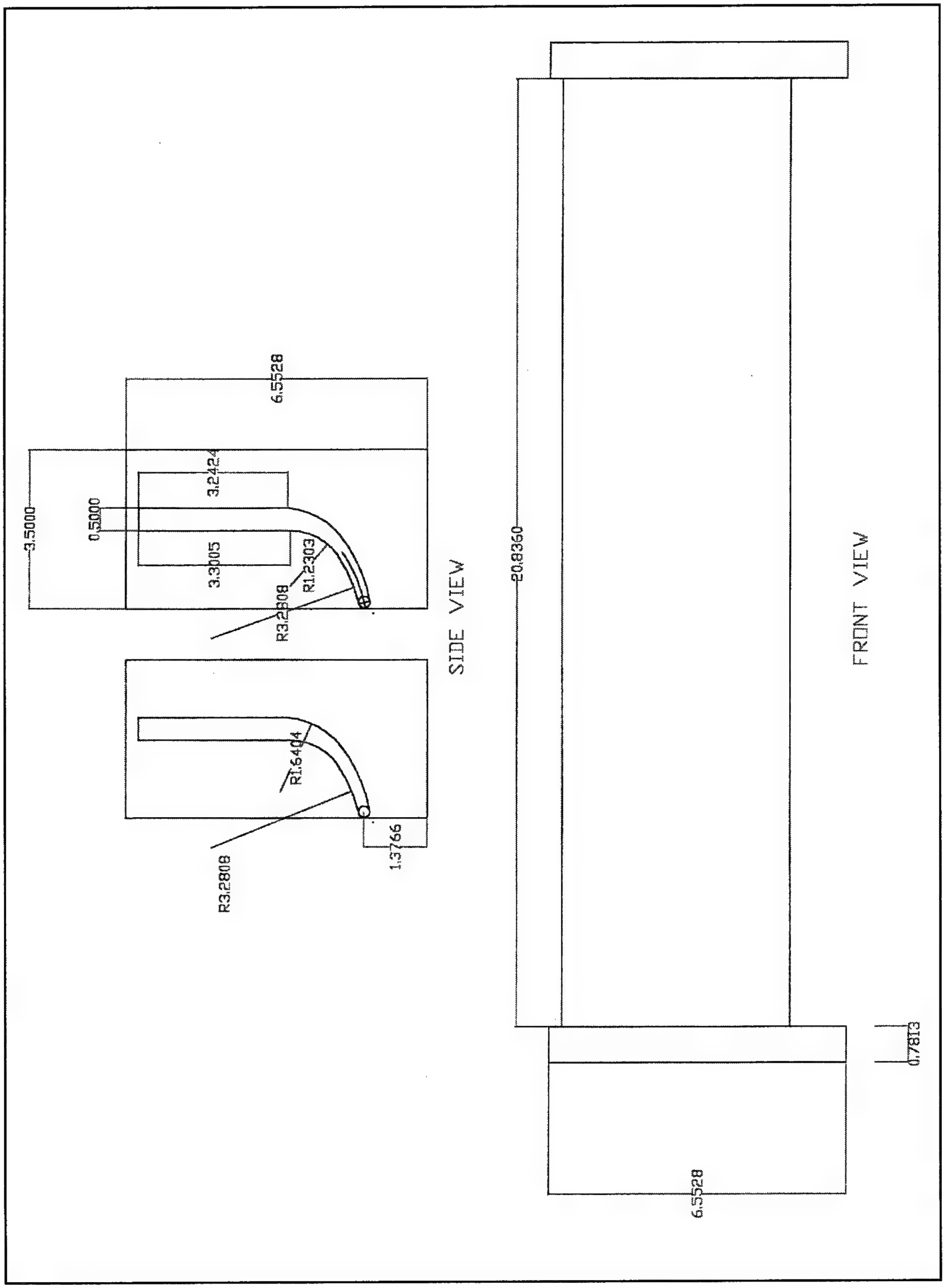


Figure 11. Vaning device number 2

screening device was nearly the same (51.4 percent). Data for this experiment are provided in Plates 34 and 35.

The ESBS was raised to a 1-ft lowered position. Vane 2 was kept in the same relative position to the ESBS as the above experiments. Velocity information was obtained in the same locations as the above experiments and can be seen in Plates 36 and 37. The amount of flow intercepted by the ESBS was calculated to be 51.1 percent, which is comparable with vane 2 and the ESBS in a 2-ft lowered position. The screen slot discharge was 547 cfs, which is less than with the ESBS and Vane 2 in a 2-ft lowered position (571 cfs).

Vane 2 was removed and replaced with Vane 1. Velocity information as obtained upstream of the ESBS and in the screen slot (Plates 38 and 39) with the ESBS in a 1-ft lowered position. Flow up the screen slot was calculated to be 503 cfs, and the amount of flow intercepted by the ESBS was 49.2 percent. These values are lower than the same ESBS position with Vane 2 in place.

Inlet Flow Vane Position Experiments

Two experiments were conducted with the relative position of the vane to the ESBS pivot point changed by 0.5 ft. Vane 2 was used for these experiments because it performed better than Vane 1.

The ESBS was lowered 1 ft when Vane 2 raised 0.5 ft. Velocity information was obtained in the throat area of the screen slot and upstream of the tip of the ESBS. The flow up the screen slot was calculated to be 543 cfs, and the flow intercepted by the ESBS was 50.9 percent This is an increase in gate-well flow of 40 cfs and an increase in intercepted flow of 1.7 percent when compared to the same ESBS elevation with Vane 2 in its original position. Velocity information from this experiment can be seen in Plates 40 and 41.

The ESBS was lowered an additional 1 ft, and Vane 2 was kept at the same relative position to the ESBS as the previous above experiment. Velocity information was obtained in the throat area of the screen slot and upstream of the ESBS (Plates 42 and 43). Flow directed up the screen slot was 610 cfs, and the amount of flow intercepted by the ESBS was calculated to be 52.2 percent. This is an increase in gatewell flow of 39 cfs and approximately the same of intercepted flow when compared to the similar experiment with the ESBS lowered 2 ft with Vane 2 in its original position. This configuration has the greatest potential for improving conditions in the screen slot and along the VBS and would be the recommended configuration to be installed at the prototype structure.

Streamlined Trashrack Experiments

The existing trashracks (Figures 12 and 13) cause a disruption in the flow immediately downstream of the trashracks (Plate 44). This disruption extends to

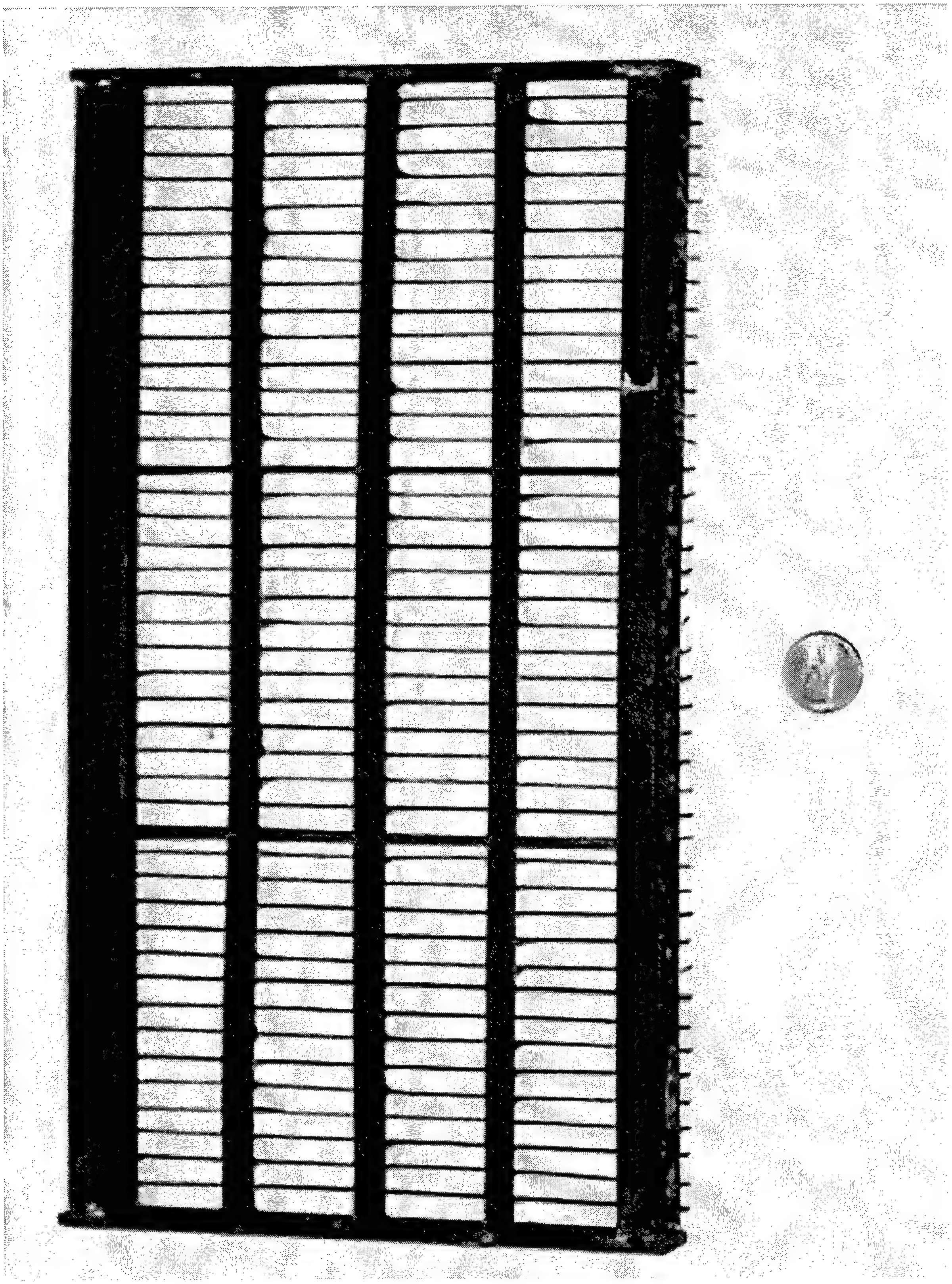


Figure 12. Model trashrack section

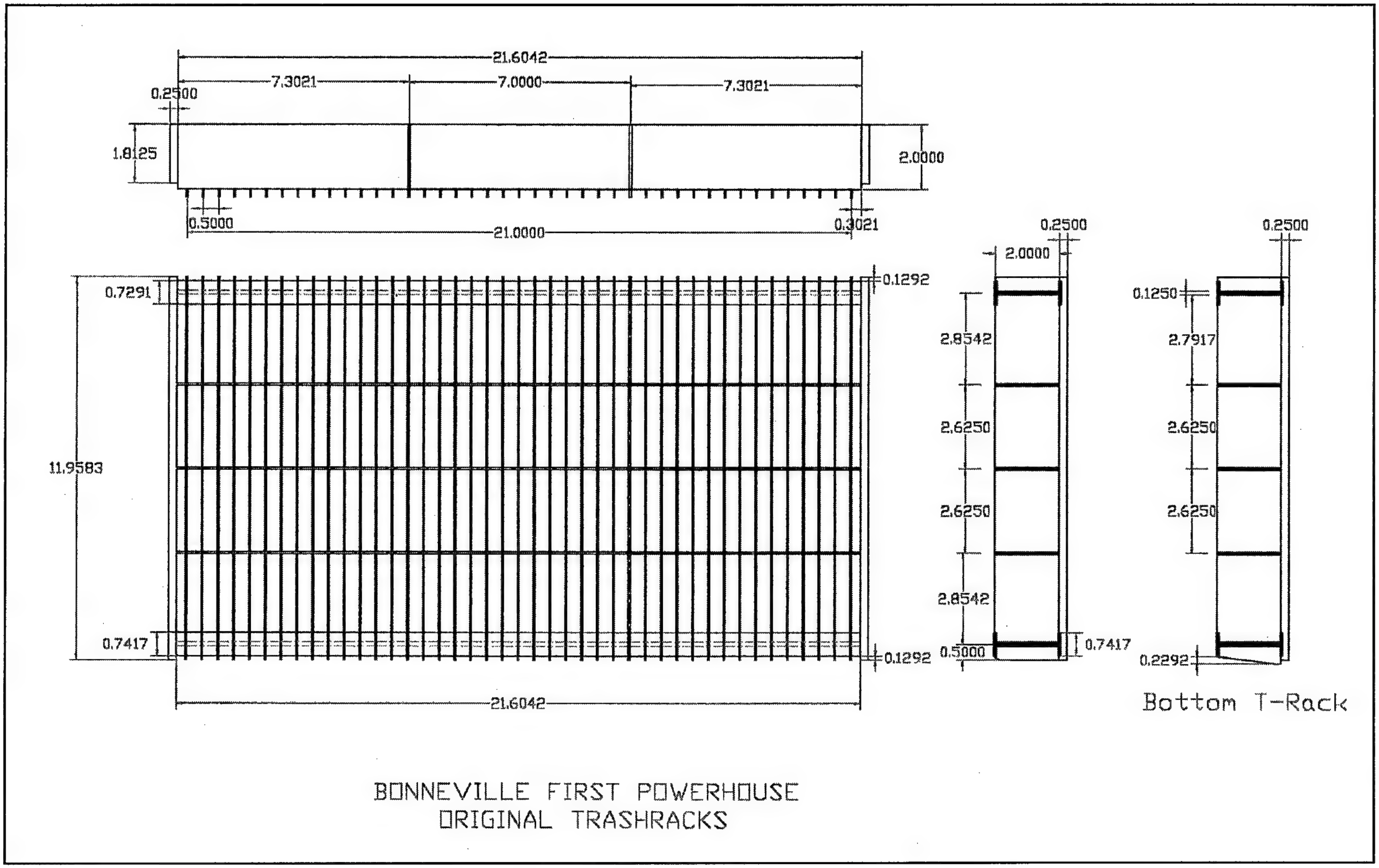


Figure 13. Original trashrack section

the face of the ESBS and has a potential for adversely affecting the efficiency of the bypass system. Fish may sense this disruption and thus influence the elevation that the fish enter the intake. Also, the disruptions at the screen face have the potential for confusing the fish, thereby causing them to swim down rather than up the screen face to the screen slot. For these reasons, it is necessary to redesign with streamlined members.

Streamlined Base Experiments

Velocity information was obtained upstream of the intake structure and downstream of the trashrack slot, with the ESBS in a 2-ft lowered position, for turbine discharges of 11,300 and 14,700 cfs. This information served as a base condition to determine the initial angles of the horizontal members of the streamlined trashracks. Velocity information obtained for these two conditions is provided in Plates 45 and 46.

Model Streamlined Trashrack Experiments

The design of the model streamlined trashracks (Figures 14) allowed for changing the angle of the streamlined members between 0 and 45 deg. The initial streamlined trashrack alignments were based on information obtained from the model with no trashracks present. The angle of the horizontal members was set to match the inflow angle at the trashracks. The angles of the internal members varied from 42 deg at the top to 15 deg at the bottom of the fifth trashrack. The angle is measured from a line perpendicular to the pier race. The bottom trashrack was not streamlined but was an existing trashrack. Some minor flow disruptions occurred at the trashrack members.

Numerous streamlined arrangements were investigated and Table 1 shows these streamlined arrangements. Velocity information obtained for these arrangements can be seen in Plates 47 through 55. Configuration 13 is the arrangement that allowed for the best flow conditions through the trashrack region. The angles of the internal members varied from 42 deg at the top of the first trashrack to 9 deg at the bottom of the fifth trashrack. The bottom trashrack was an existing trashrack section. Velocity information from the model with configuration 13 is provided in Plate 53.

Unit 8 Experiments

All previous streamlined trashracks were performed with topography representing units 1 through 5. The initial prototype experiments will be performed in unit 7 or 8. The topography in front of these units differs from the topography in front of units 1 through 5. Two experiments were conducted to ensure that the configuration 13 streamlined trashrack arrangement would work well with the unit 8 topography. Data from these two experiments can be seen in Plates 56 and 57. Streamlined trashrack configuration 13 works well with the unit 7/8 topography.

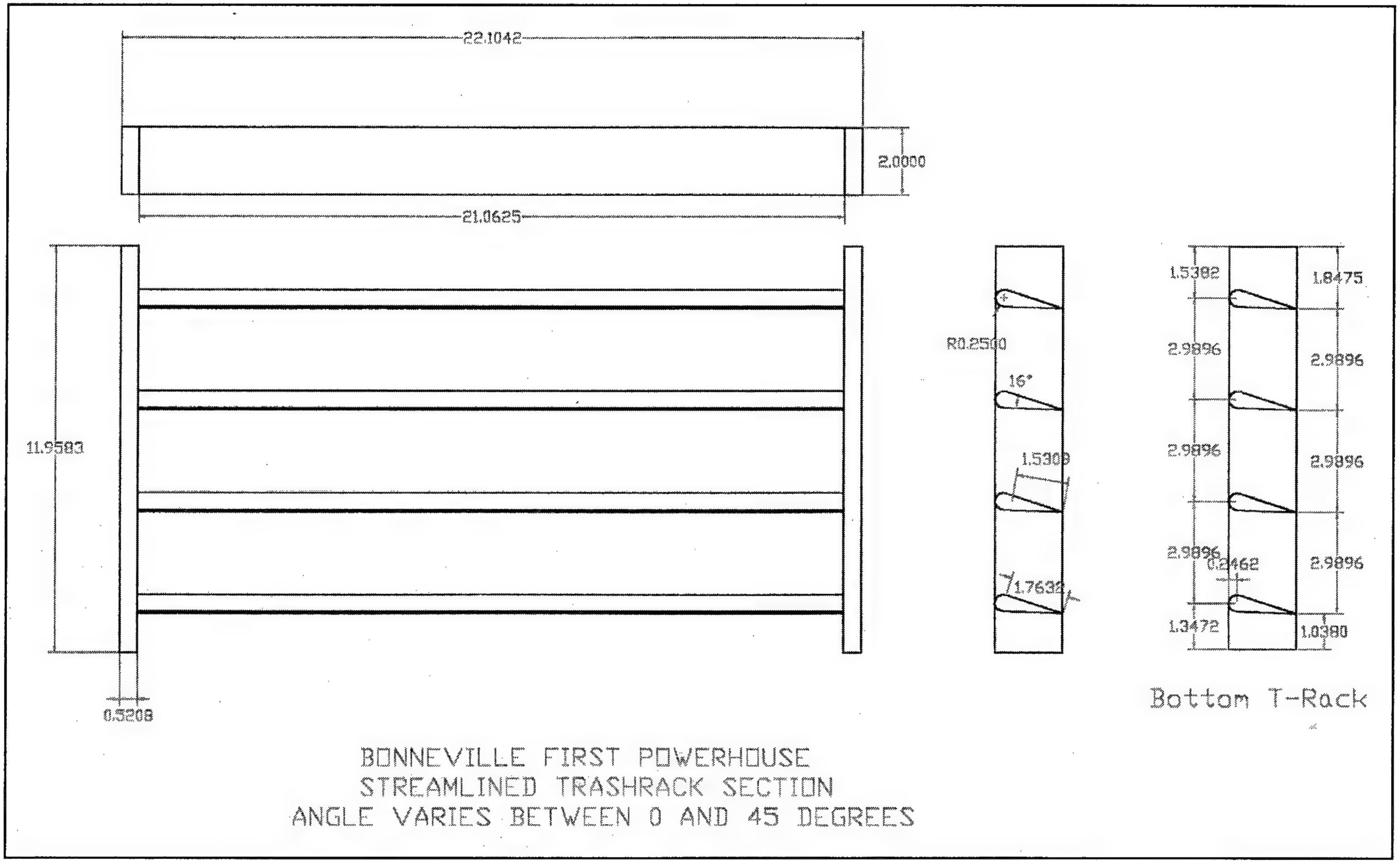


Figure 14. Streamlined trashrack section

6 Pier Extension Experiments

The upstream tip of the ESBS is only 5.5 ft downstream of the trashracks. Other projects on the Columbia and Snake Rivers that have FGE systems with ESBSs have comparable distances of greater than 18 ft. These guidance systems perform well. In contrast, Bonneville Second Powerhouse has STSs with a tip of screen to trashrack distance of 8 ft. This FGE system does not perform well. It may be possible for fish to feel the effects of the screen upstream of the trashracks. It would make sense to maximize the distance between the trashracks and the ESBS screen face to decrease the potential for fish to sound deeper outside of the trashracks because of the close proximity of the screen and trashracks.

Numerous experiments were conducted to investigate the relationship of the distance between the tip of the ESBS and the trashracks location. These experiments involved moving the trashrack to the upstream end of the existing pier nose, installing 10-, 15-, and 20-ft pier extensions.

Trashracks Moved to Pier Nose

Relocating the trashrack at the upstream end of the pier nose would increase the distance from the trashrack to the tip of the screen from 5.5 to 12.5 ft. An acrylic frame was constructed and installed in the model at the upstream end of the existing pier nose. This frame consisted of plastic vertical runners with brass strips attached as a support for the trashracks. Velocity information was obtained upstream and downstream of the new trashrack location with the ESBS in a 2-ft lowered position for a turbine loading of 14,700 cfs (Plate 58). These data were used to determine the streamlined trashrack arrangement for initial experiments.

Several experiments were conducted to identify the optimum streamlined trashrack arrangement with the trashracks located at the upstream end of the existing pier nose. The optimum arrangement would be the arrangement that had the least effect on the flow passing through its internal members. Velocity information obtained for these experiments is provided in Plates 59 through 62. The streamlined arrangements for these experiments are provided in Table 2. The optimum arrangement was configuration 5. The internal members of the streamlined trashracks varied from 13 deg at the top to 9 deg at the sixth

trashrack. The bottom trashracks were an existing trashrack panel. The angle of the trashrack members is measured from a perpendicular line to the alignment of the face of the dam. The steepest internal member was angled at 16 deg. These angles are flatter than the angles required to give undisturbed flow with the streamlined trashracks in their original position. This is an improvement because the downward flow component is smaller at the pier nose trashrack, which should be a benefit in fish guidance.

One additional experiment was conducted to determine if the streamlined trashracks could be designed with one internal member alignment. An arrangement with the internal members set at 13.7 deg was investigated. It gave satisfactory results. However, it would be recommended to install configuration 5 at the prototype structure if the trashracks are moved to the upstream tip of the pier noses. This configuration matches the flow lines into the intake structure with the least disturbance. Velocity information from this experiment is provided in Plate 62.

Roof Extensions with Trashrack at Pier Nose

There was a concern that fish may hold in the area between the top trashrack and the closed sluiceway gates. A series of experiments were conducted to investigate the potential for adding a roof extension that would exclude fish from this area. This roof extension consisted of a flat plate that extended upstream from the el 68.0 shelf to the top of the second trashrack. Experiments were also conducted with this arrangement and a plate extending from the top of the second trashrack to the water surface along the same slope as the pier.

Numerous experiments were conducted to find the best roof extension and streamlined trashrack arrangement. Velocity information for these experiments is provided in Plates 63 through 71. The arrangements that provided the best roof alignment and streamlined trashrack arrangement was configurations 7 and 9. Configuration 7 consisted of a roof extension that extended from the el 68.0 shelf to the top of the second trashrack. The streamlined internal angle arrangement varied from 10 deg at top of the second trashrack to 9 deg at the bottom of the sixth trashrack. The steepest angled member was 14 deg. Configuration 9 had the same roof extension arrangement except a plate extended from the top of the second trashrack to the water surface along the pier slope. The streamlined internal arrangement varied from 31.8 deg at the top of the second trashrack to 9 deg at the bottom of the sixth trashrack. Velocity information obtained for these two experiments is provided in Plates 65 and 69. The internal streamlined trashrack arrangement is provided in Table 2. Configuration 9 would be the recommended arrangement because it allows for total exclusion of fish above the trashracks and between the trashracks and the sluice gates. Additional design work must be undertaken to use the sluiceway for trash removal.

Unit 8 Topography with Trashracks at Pier Nose

Two experiments were conducted with the unit 8 topography installed in the model. The first experiment involved obtaining data with existing trashracks installed in the top and bottom positions. The internal five trashracks were streamlined with all members set at a constant 12-deg angle. Velocity information for this experiment is provided in Plate 73. This arrangement provided acceptable flow conditions through the trashrack area with minimal disruption of flow downstream of the trashrack. A better arrangement could be obtained through further investigations. The second experiment involved using a reverse configuration 13 arrangement that was obtained during the streamlined trashrack investigation with these trashracks in their original positions. This experiment was conducted to determine if the streamlined trashracks that were constructed for prototype experiments with trashracks located in their original positions could be used for prototype experiments with the streamlined trashracks located at the pier nose. The top and bottom trashracks were of the original trashrack design. The internal trashracks were a reverse configuration 13. That is the top trashrack was used as the bottom and the bottom as the top, the second from the top was used as the second from the bottom and vice versus. The actual configuration is provided in Table 2 and velocity information obtained for this experiment is provided in Plate 74. This configuration did not give a satisfactory flow condition through the trashrack region. The effect of the internal members of the streamlined trashracks on flow immediately upstream of the streamlined trashrack members can be seen in Plate 74. This implies that new streamlined trashracks must be fabricated if the trashracks were relocated to the upstream end of the pier nose.

10-ft Pier Extensions

Pier extensions in the length of 10 ft were added to each of the existing piers. These pier extensions had a rounded pier nose that was identical to the existing pier nose shape. With this extension in place, the distance between the tip of the ESBS and the trashrack was increased to 15.3 ft. Velocity information was collected upstream and downstream of the new trashrack location for three experiments. The conditions for the 10-ft pier extension are provided in Table 3.

The first experiment involved documenting the velocity profiles with the 10-ft extension in place but without trashracks. The ESBS was in a 2-ft lowered position, and the turbine loading was 11,300 cfs. This experiment was conducted as a basis for the initial streamlined trashrack experiment. Velocity information for this experiment is provided in Plate 75.

The other two experiments were conducted with two different streamlined trashrack arrangements in place for a turbine loading of 11,300 cfs. The ESBS was in 2-ft lowered position. One experiment was conducted with the angle of the streamlined trashracks set at 13.7 deg and the other with the angles set at 15.7-deg. The arrangement with the 13.7-deg setting provided a slightly better flow condition through the trashrack area than with the 15.7-deg setting. This

can be seen by comparing velocities in the vicinity of trashrack locations in Plates 76 and 77.

15-ft Pier Extensions

Pier extensions in the length of 15 ft were added to each of the existing piers. These pier extensions had a rounded pier nose that was identical to the existing pier nose shape. With this extension in place, the distance between the tip of the ESBS and the trashrack was increased to 20.3 ft. Velocity information was collected upstream and downstream of the new trashrack location for three experiments. The conditions for the 10-ft pier extension are provided in Table 3.

The first experiment involved documenting the velocity profiles with the 15-ft extension in place but without trashracks. The ESBS was in a 2-ft lowered position and the turbine loading was 11,300 cfs. This experiment was conducted as a basis for the initial streamlined trashrack experiment. Velocity information for this experiment is provided in Plate 78.

The other experiment was conducted with two different streamlined trashrack arrangements in place for a turbine loading of 11,300 cfs. The ESBS was in a 2-ft lowered position. One angle setting of the streamlined trashracks was at 9 deg, while the other angle setting was at 12 deg. The arrangement with the 12-deg setting provided a slightly better flow condition through the trashrack area than the arrangement with a 9-deg setting (compare Plate 79 with Plate 80).

20-ft Pier Extensions

Pier extensions in the length of 20 ft were added to each of the existing piers. These pier extensions had a rounded pier nose that was identical to the existing pier nose shape. With this extension in place, the distance between the tip of the ESBS and the trashrack was increased to 25.1 ft. Velocity information was collected upstream and downstream of the new trashrack location for three experiments. The conditions for the 20-ft pier extension are provided in Table 3.

The first experiment involved document the velocity profiles with the 20-ft extension in place but without and trashracks. The ESBS was in a 2-ft lowered position and the turbine loading was 11,300 cfs. This experiment was conducted as a basis for the initial streamlined trashrack experiment. Velocity information for this experiment is provided in Plate 81.

The other experiments were conducted with two different streamlined trashrack arrangements in place for a turbine loading of 11,300 cfs. The ESBS was in 2-ft lowered position. One was conducted with the angle of the streamlined trashracks set at 9 deg and the other with the angles set at 5.1 deg. The arrangement with the 5.1-deg arrangement provided a slightly better flow condition through the trashrack area than the 9-deg arrangement (compare Plate 82 with Plate 83).

20-ft Pier Extensions with Box-Beam Trashracks

Three experiments were conducted with the streamlined trashracks removed and replaced with trashracks that had box beams as horizontal support members. Velocity information was obtained upstream and downstream of the trashracks with the box beam rotated 5.1 deg and in a horizontal position at a turbine loading of 11,300 cfs. Neither configuration resulted in acceptable flow conditions in the vicinity of the box-beam trashrack members (Plates 84 through 86). Velocity information was also obtained with the box-beam rotated 5.1 deg at a turbine loading of 14,700 cfs. This experiment also indicated poor flow conditions through the trashrack area (Plate 84) Based on these experiments, it is apparent that, with a 20-ft pier extension, streamlined trashrack are better for reducing turbulent flow downstream of the trashracks than a box-beam arrangement.

20-ft Pier Extensions with Roof Extensions

Two experiments were conducted to investigate whether or not roof extensions would help guide surface flow into the intake structure. Velocity information was obtained in the vicinity of the top three streamlined trashracks for two different roof extensions. The first roof extension extended from a point tangent to the roofline inside of the intake structure to the water surface at the halfway point between the new trashrack location and the original trashrack location. The second roof extension extended from a point tangent to the roofline inside of the intake structure to the water surface at the top of the new trashrack location. Velocity information obtained from these experiments as well as the roof extension arrangement is provided in Plates 87 and 88. Either roof extension would be an improvement. The shorter one would cost less and showed lower accelerations along the roof, and this one would be the recommended design. However, more study would be required before a final decision could be made on what should be added to the prototype structure.

7 Conclusions and Recommendations

The present FGE system utilizes a 20-ft-long traveling screen to collect juvenile salmon entering the intake structure. This screen should be replaced with a 40-foot-long extended submerged bar screen. This screen should have an internal 48 percent porosity plate to control the flow through the screen. This will increase the amount of flow that is intercepted by the FGE system from 23.2 to approximately 52 percent, which should increase the potential for intercepting greater numbers of fish. This screen should be biologically evaluated at the prototype structure.

Vane 2 is the recommended vane design to be used in conjunction with the ESBS in a 1- or 2-ft lowered position. As flow enters, the screen slot flow separation occurs. This results in inefficient entrance conditions, highly turbulent flow in the gate well, and high velocities that concentrate along the surface of the vertical barrier screen. Each of these reduces the potential to intercept fish and to safely protect them until they pass out of the screen slot area. A vaning device is needed to reduce the flow separation and slot turbulence. The vaning device also distributes the flow across the slot, which reduces the high velocities occurring along the screen face. This screen and vane arrangement should be biologically evaluated at the prototype structure.

The existing trashrack arrangement cause flow disturbances that propagate to the surface of the screening device. This potentially will have a negative effect on FGE. The top five trashracks should be replaced with a streamlined trashrack arrangement. The configuration 13 provided the best flow conditions through the trashracks onto the screen face, with the trashracks located in their original position.

The tip of the ESBS is located only 5.5 ft downstream of the existing trashrack arrangement. At other projects that have a successful screening system, this distance exceeds 18 ft. To ensure that the purposed extended bypass screen has the greatest potential for collecting fish this distance should be increased. Several alternate locations were investigated. Either 15- or 20-ft pier extensions would be recommended. These pier extensions move the trashrack to a position where the downward component of the flow is greatly reduced. Of course, the longer the pier extensions, the greater the cost. A biological experiment at the prototype structure should be performed to evaluate pier extensions. Streamlined

trashracks that were designed for the pier extensions should be used if pier extensions are chosen to be installed at the prototype structure. The correct trashrack arrangement should be used for each pier extension.

Roof extension improves entrance conditions with the trashrack moved upstream to alternate positions. Further investigation is needed before a final recommendation on roof design can be made.

Unit 8 topography has little effect on the streamlined trashrack arrangement.

Table 1
Bonneville First Powerhouse Streamlined Trashrack Experiments

		BASE TEST TEST 71	BASE TEST TEST 70	BASE TEST TEST 86	CONFIG 1 TEST 69	CONFIG 10 TEST 87	CONFIG 11 TEST 88	CONFIG 12 TEST 89
Q, CFS		14700	14700	11300	11300	11300	11300	11300
ESBS POSITION		2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER
TOPOGRAPHY		UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5
	TRASHRACK MEMBER #	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG
T-RACK #1(TOP)	1	NORMAL	WOUT	WOUT	42	42	42	42
	2	NORMAL	WOUT	WOUT	35	37	37	37
	3	NORMAL	WOUT	WOUT	26	33	31	31
	4	NORMAL	WOUT	WOUT	21	28	26	26
T-RACK #2	1	NORMAL	WOUT	WOUT	19	25	22	22
	2	NORMAL	WOUT	WOUT	17	22	22	22
	3	NORMAL	WOUT	WOUT	16	22	22	20
	4	NORMAL	WOUT	WOUT	15	19	19	19
T-RACK #3	1	NORMAL	WOUT	WOUT	15	18	18	18
	2	NORMAL	WOUT	WOUT	12	18	15	15
	3	NORMAL	WOUT	WOUT	13	19	14	14
	4	NORMAL	WOUT	WOUT	11	20	16	16
T-RACK #4	1	NORMAL	WOUT	WOUT	11	21	16	16
	2	NORMAL	WOUT	WOUT	16	23	17	17
	3	NORMAL	WOUT	WOUT	14	24	20	17
	4	NORMAL	WOUT	WOUT	15	28	24	21
T-RACK #5	1	NORMAL	WOUT	WOUT	19	29	24	21
	2	NORMAL	WOUT	WOUT	19	27	24	21
	3	NORMAL	WOUT	WOUT	17	17	17	17
	4	NORMAL	WOUT	WOUT	15	12	9	9
T-RACK #6 (BOT)	1	NORMAL	WOUT	WOUT	NORMAL	NORMAL	NORMAL	NORMAL
	2	NORMAL	WOUT	WOUT	NORMAL	NORMAL	NORMAL	NORMAL
	3	NORMAL	WOUT	WOUT	NORMAL	NORMAL	NORMAL	NORMAL
	4	NORMAL	WOUT	WOUT	NORMAL	NORMAL	NORMAL	NORMAL

Table 2
Bonneville First Powerhouse Trashrack at Pier Nose Experiments

		BASE TEST TEST 75	CONFIG 2 TEST 72	CONFIG 3 TEST 73	CONFIG 3 TEST 74	CONFIG 5 TEST 76	CONFIG 6 TEST 77	CONFIG 6 TEST 78	CONFIG 7 TEST 79	TEST 80
Q, CFS		14700	14700	14700	14700	14700	14700	14700	14700	14700
ESBS POSITION		2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER
TOPOGRAPHY		UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5
	TRASHRACK MEMBER #	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG
T-RACK #1(TOP)	1	WOUT	31.5	WOUT	21.5	13	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT
	2	WOUT	29.7	WOUT	20	13	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT
	3	WOUT	31.9	WOUT	21.5	13	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT
	4	WOUT	31.8	WOUT	21.5	13	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT
T-RACK #2	1	WOUT	31.5	21.5	22	13	13	13	10	NORMAL
	2	WOUT	29.8	20	20	15	15	15	12	NORMAL
	3	WOUT	31.9	21.5	22	16	16	16	13	NORMAL
	4	WOUT	31.9	21.5	22	16	16	16	13	NORMAL
T-RACK #3	1	WOUT	31.8	22	20	16	16	16	13	NORMAL
	2	WOUT	30.5	20	20.5	14	14	14	12	NORMAL
	3	WOUT	30.5	22	20.5	15	15	15	13	NORMAL
	4	WOUT	28.8	22	19	14	14	14	14	NORMAL
T-RACK #4	1	WOUT	29.9	20	20	14	14	14	11	NORMAL
	2	WOUT	29.2	20.5	19.5	13	13	13	13	NORMAL
	3	WOUT	25.3	20.5	16	13	13	13	11	NORMAL
	4	WOUT	26.2	19	16.5	13	13	13	11	NORMAL
T-RACK #5	1	WOUT	28.2	20	18	13	13	13	10	NORMAL
	2	WOUT	27.9	19.5	20	13	13	13	10	NORMAL
	3	WOUT	25.5	16	15.5	13	13	13	10	NORMAL
	4	WOUT	23.9	16.5	13.5	12	12	12	9	NORMAL
T-RACK #6	1	WOUT	25.6	18	13.5	10	10	10	9	NORMAL
	2	WOUT	22	20	12.5	9	9	9	9	NORMAL
	3	WOUT	17.6	15.5	9	9	9	9	9	NORMAL
	4	WOUT	17.6	13.5	9	9	9	9	9	NORMAL
T-RACK #7 (BOT)	1	WOUT	NORMAL	13.5	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
	2	WOUT	NORMAL	12.5	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
	3	WOUT	NORMAL	9	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL
	4	WOUT	NORMAL	9	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL	NORMAL

(Continued)

Table 2 (Concluded)

		CONFIG 8 TEST 81	BASE TEST 82	CONFIG 9 TEST 83	CONFIG 9 TEST 84	BASE TEST 85	TEST 113	TEST 124	CONFIG 13 TEST 125
Q, CFS		14700	11300	11300	14700	14700	11300	11300	11300
ESBS POSITION		2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	1 FT LOWER	1 FT LOWER	1 FT LOWER
TOPOGRAPHY		UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNITS 1-5	UNIT 8	UNIT 8
	TRASHRACK MEMBER #	MEMBER ANGLE	MEMBER ANGLE	MEMBER ANGLE	MEMBER ANGLE	MEMBER ANGLE	MEMBER ANGLE	MEMBER ANGLE	MEMBER ANGLE
TRACK #1(TOP)	1	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT	13.7	NORMAL	NORMAL
	2	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT	13.7	NORMAL	NORMAL
	3	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT	13.7	NORMAL	NORMAL
	4	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT	ROOF EXT	13.7	NORMAL	NORMAL
TRACK #2	1	9	WOUT	31.8	31.8	WOUT	13.7	12	42
	2	9	WOUT	17.9	17.9	WOUT	13.7	12	37
	3	9	WOUT	14.7	14.7	WOUT	13.7	12	31
	4	9	WOUT	13	13	WOUT	13.7	12	26
TRACK #3	1	9	WOUT	13	13	WOUT	13.7	12	22
	2	9	WOUT	9	9	WOUT	13.7	12	22
	3	9	WOUT	9	9	WOUT	13.7	12	20
	4	9	WOUT	9	9	WOUT	13.7	12	19
TRACK #4	1	9	WOUT	9.6	9.6	WOUT	13.7	12	18
	2	9	WOUT	9.4	9.4	WOUT	13.7	12	15
	3	9	WOUT	9.4	9.4	WOUT	13.7	12	14
	4	9	WOUT	9.7	9.7	WOUT	13.7	12	16
TRACK #5	1	9	WOUT	9	9	WOUT	13.7	12	14
	2	9	WOUT	9	9	WOUT	13.7	12	14
	3	9	WOUT	9	9	WOUT	13.7	12	15
	4	9	WOUT	9	9	WOUT	13.7	12	17
TRACK #6	1	9	WOUT	9	9	WOUT	13.7	12	17
	2	9	WOUT	9	9	WOUT	13.7	12	17
	3	9	WOUT	9	9	WOUT	13.7	12	17
	4	9	WOUT	9	9	WOUT	13.7	12	9
TRACK #7 (BOT)	1	NORMAL	WOUT	NORMAL	NORMAL	WOUT	13.7	NORMAL	NORMAL
	2	NORMAL	WOUT	NORMAL	NORMAL	WOUT	13.7	NORMAL	NORMAL
	3	NORMAL	WOUT	NORMAL	NORMAL	WOUT	13.7	NORMAL	NORMAL
	4	NORMAL	WOUT	NORMAL	NORMAL	WOUT	13.7	NORMAL	NORMAL

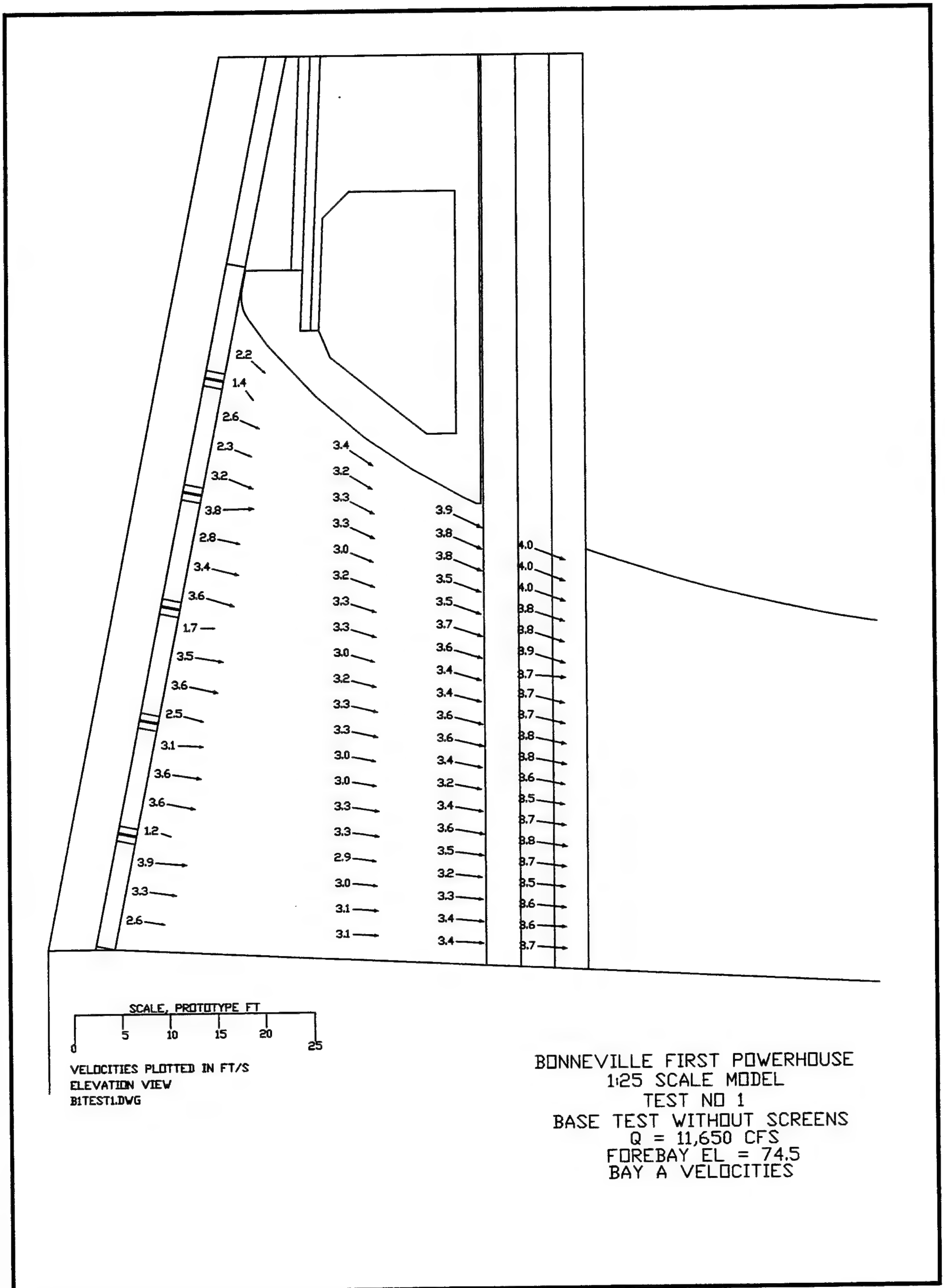
Table 3
Bonneville First Powerhouse Trashrack Pier Nose Extensions Experiments

		BASE TEST TEST 100	TEST 101	BASE TEST TEST 102	TEST 103	TEST 104	TEST 105	TEST 106	TEST 107
Q, CFS		11300	11300	11300	11300	11300	11300	14700	14700
ESBS POSITION		2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER
PIER EXTENSION		20 FT	20 FT	15 FT	15 FT	20 FT	20 FT	20 FT	20 FT
T-RACK TYPE		WITHOUT	STREAMLINED	WITHOUT	STREAMLINED	STREAMLINED	BOX BEAM	BOX BEAM	BOX BEAM
ROOF EXTENSION		WITHOUT	WITHOUT	WITHOUT	WITHOUT	WITHOUT	WITHOUT	WITHOUT	WITHOUT
	TRASHRACK MEMBER #	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE,DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG
T-RACK #1(TOP)	1	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	2	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	3	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	4	WOUT	9	WOUT	9	5.1	5.1	5.1	0
T-RACK #2	1	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	2	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	3	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	4	WOUT	9	WOUT	9	5.1	5.1	5.1	0
T-RACK #3	1	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	2	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	3	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	4	WOUT	9	WOUT	9	5.1	5.1	5.1	0
T-RACK #4	1	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	2	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	3	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	4	WOUT	9	WOUT	9	5.1	5.1	5.1	0
T-RACK #5	1	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	2	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	3	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	4	WOUT	9	WOUT	9	5.1	5.1	5.1	0
T-RACK #6	1	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	2	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	3	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	4	WOUT	9	WOUT	9	5.1	5.1	5.1	0
T-RACK #7 (BOT)	1	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	2	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	3	WOUT	9	WOUT	9	5.1	5.1	5.1	0
	4	WOUT	9	WOUT	9	5.1	5.1	5.1	0

(Continued)

Table 3 (Concluded)

		TEST 108	TEST 109	TEST 110	BASE TEST TEST 112	TEST 114	TEST 115
Q, CFS		11300	11300	11300	11300	11300	11300
ESBS POSITION		2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER	2 FT LOWER
PIER EXTENSION		20 FT	20 FT	15 FT	10 FT	10 FT	10 FT
T-RACK TYPE		STREAMLINED	STREAMLINED	STREAMLINED	WITHOUT	STREAMLINED	STREAMLINED
ROOF EXTENSION		IN PLACE	IN PLACE	WITHOUT	WITHOUT	WITHOUT	WITHOUT
	TRASHRACK MEMBER #	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE, DEG	MEMBER ANGLE,DEG	MEMBER ANGLE, DEG
T-RACK #1(TOP)	1	5.1	5.1	12	WOUT	13.7	15.7
	2	5.1	5.1	12	WOUT	13.7	15.7
	3	5.1	5.1	12	WOUT	13.7	15.7
	4	5.1	5.1	12	WOUT	13.7	15.7
T-RACK #2	1	5.1	5.1	12	WOUT	13.7	15.7
	2	5.1	5.1	12	WOUT	13.7	15.7
	3	5.1	5.1	12	WOUT	13.7	15.7
	4	5.1	5.1	12	WOUT	13.7	15.7
T-RACK #3	1	5.1	5.1	12	WOUT	13.7	15.7
	2	5.1	5.1	12	WOUT	13.7	15.7
	3	5.1	5.1	12	WOUT	13.7	15.7
	4	5.1	5.1	12	WOUT	13.7	15.7
T-RACK #4	1	5.1	5.1	12	WOUT	13.7	15.7
	2	5.1	5.1	12	WOUT	13.7	15.7
	3	5.1	5.1	12	WOUT	13.7	15.7
	4	5.1	5.1	12	WOUT	13.7	15.7
T-RACK #5	1	5.1	5.1	12	WOUT	13.7	15.7
	2	5.1	5.1	12	WOUT	13.7	15.7
	3	5.1	5.1	12	WOUT	13.7	15.7
	4	5.1	5.1	12	WOUT	13.7	15.7
T-RACK #6	1	5.1	5.1	12	WOUT	13.7	15.7
	2	5.1	5.1	12	WOUT	13.7	15.7
	3	5.1	5.1	12	WOUT	13.7	15.7
	4	5.1	5.1	12	WOUT	13.7	15.7
T-RACK #7 (BOT)	1	5.1	5.1	12	WOUT	13.7	15.7
	2	5.1	5.1	12	WOUT	13.7	15.7
	3	5.1	5.1	12	WOUT	13.7	15.7
	4	5.1	5.1	12	WOUT	13.7	15.7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3.7
SCALE, PROTOTYPE FT
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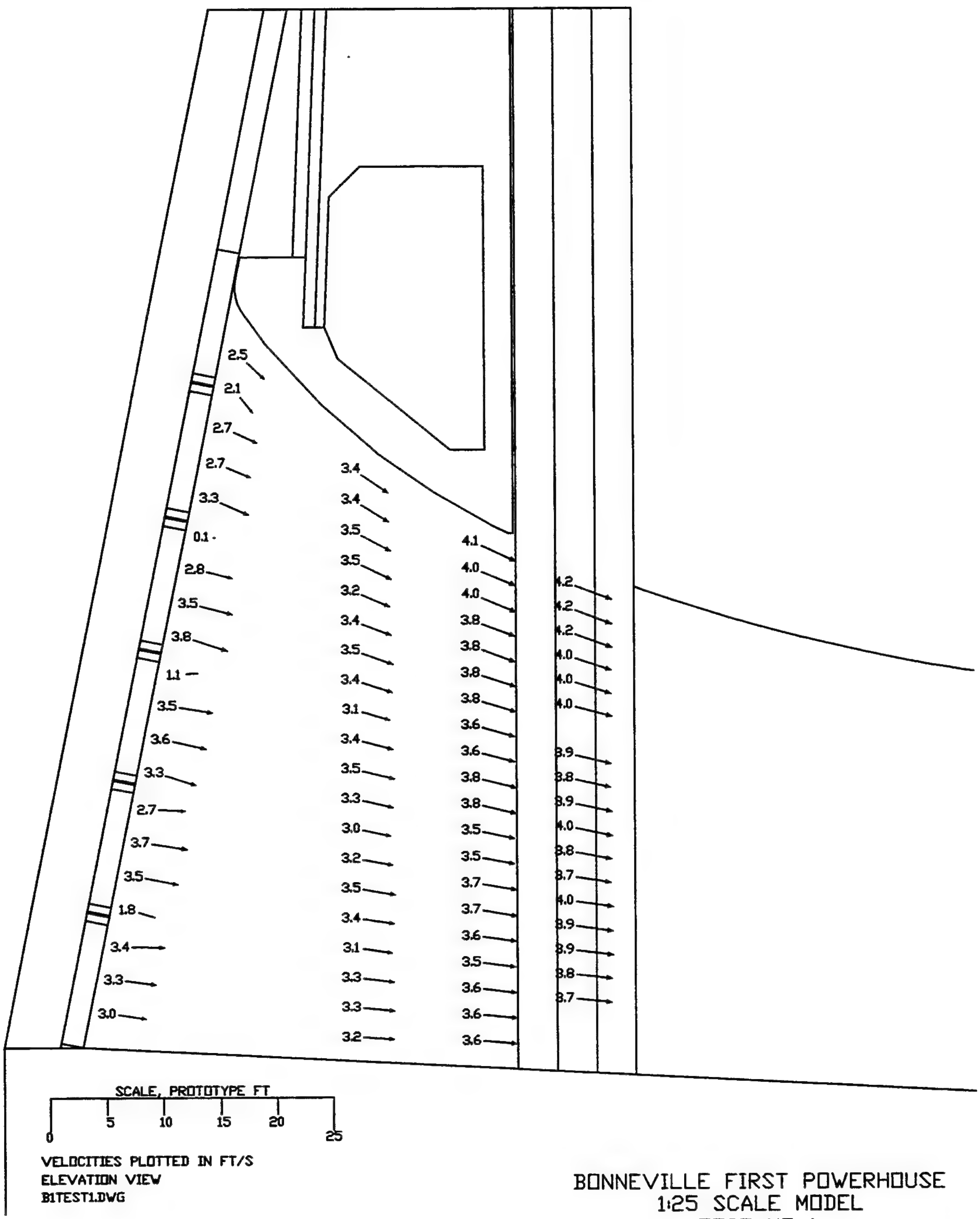
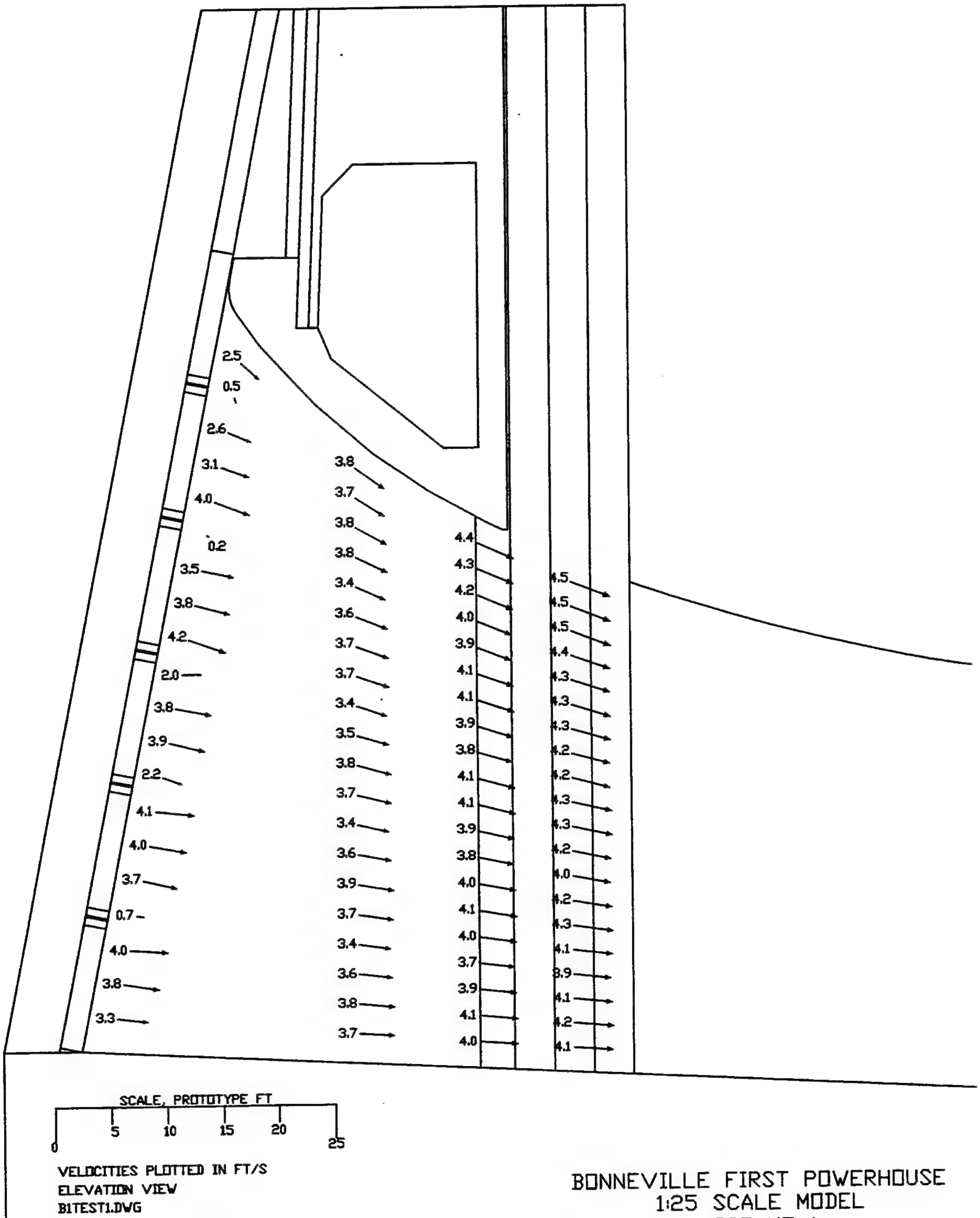
5
10
15
20
25
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST1.DWG
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST NO 1
BASE TEST WITHOUT SCREENS
Q = 11,650 CFS
FOREBAY EL = 74.5
BAY A VELOCITIES

PLATE 1

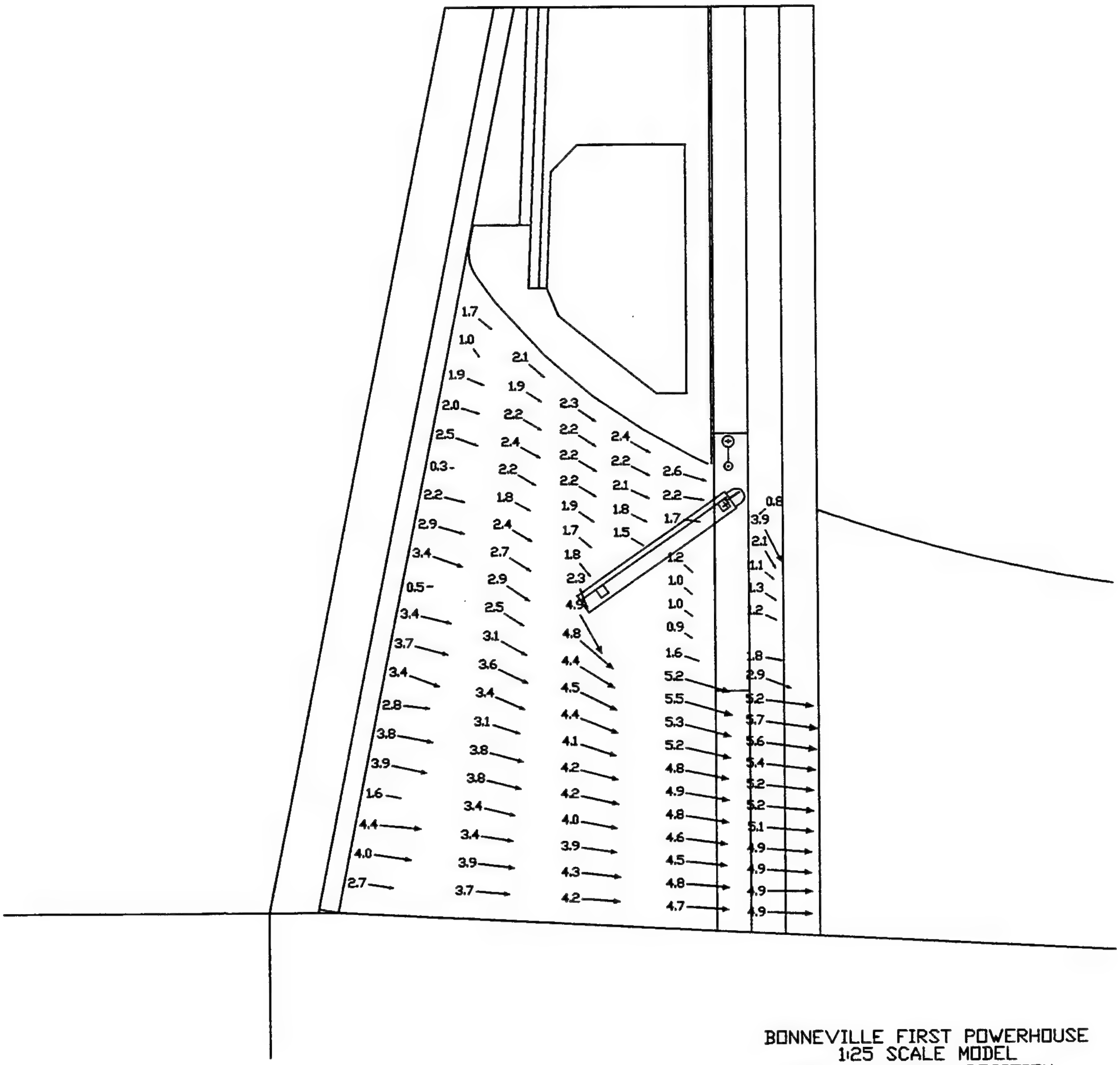


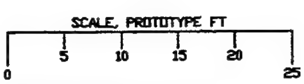
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST NO 1
BASE TEST WITHOUT SCREENS
Q = 11,650 CFS
FOREBAY EL = 74.5
BAY B VELOCITIES



BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST NO 1
BASE TEST WITHOUT SCREENS
Q = 11,650 CFS
FOREBAY EL = 74.5
BAY C VELOCITIES

PLATE 3

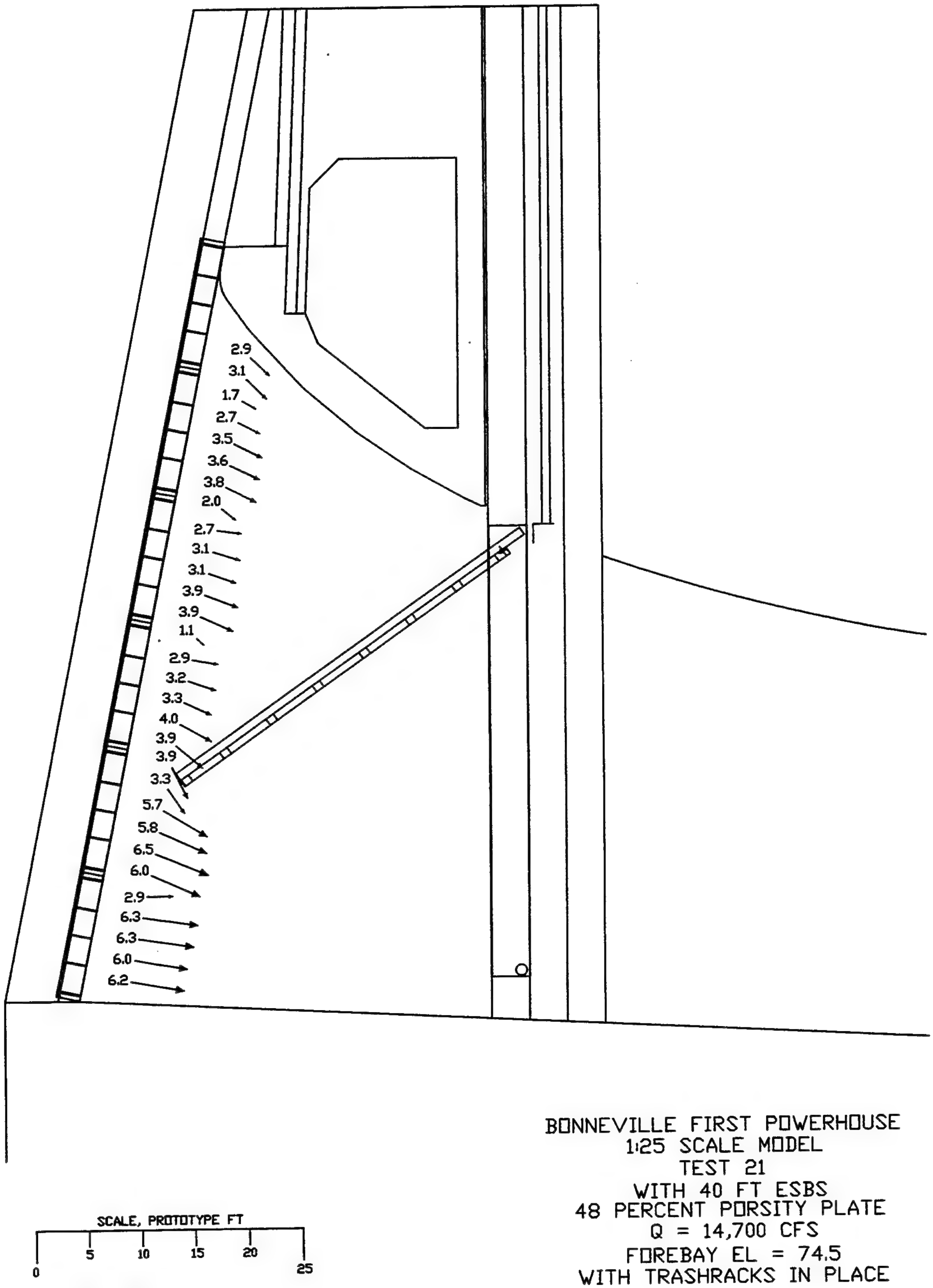




VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1FGEPLAT4.DWG

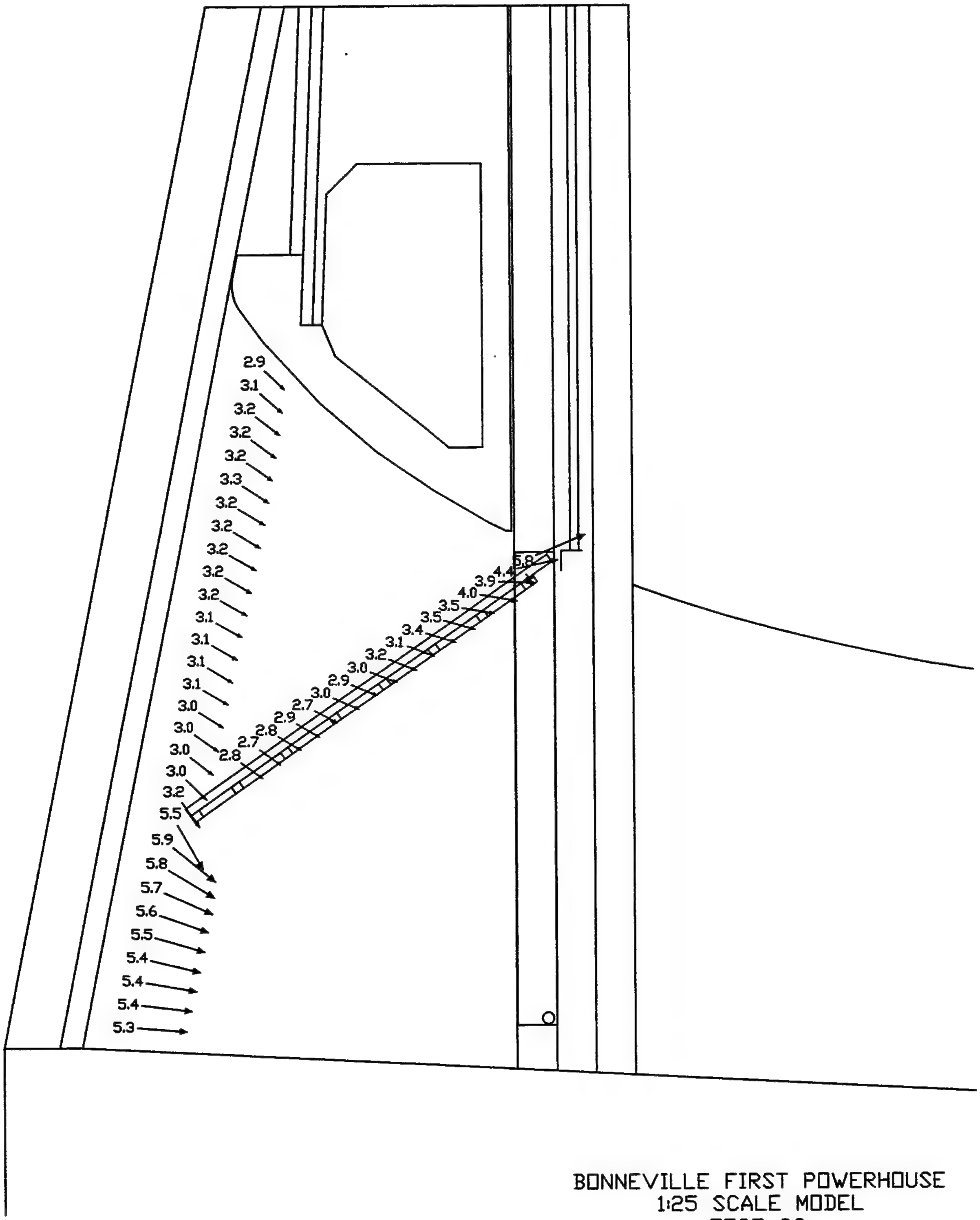
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
STS IN NORMAL POSITION
Q = 11,300 CFS
FOREBAY EL = 74.5
AVERAGE VELOCITIES IN BAY C

PLATE 4



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST21.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 21
WITH 40 FT ESBS
48 PERCENT PORSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH TRASHRACKS IN PLACE



BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 22
WITH 40 FT ESBS
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS

SCALE, PROTOTYPE FT
0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST22.DWG

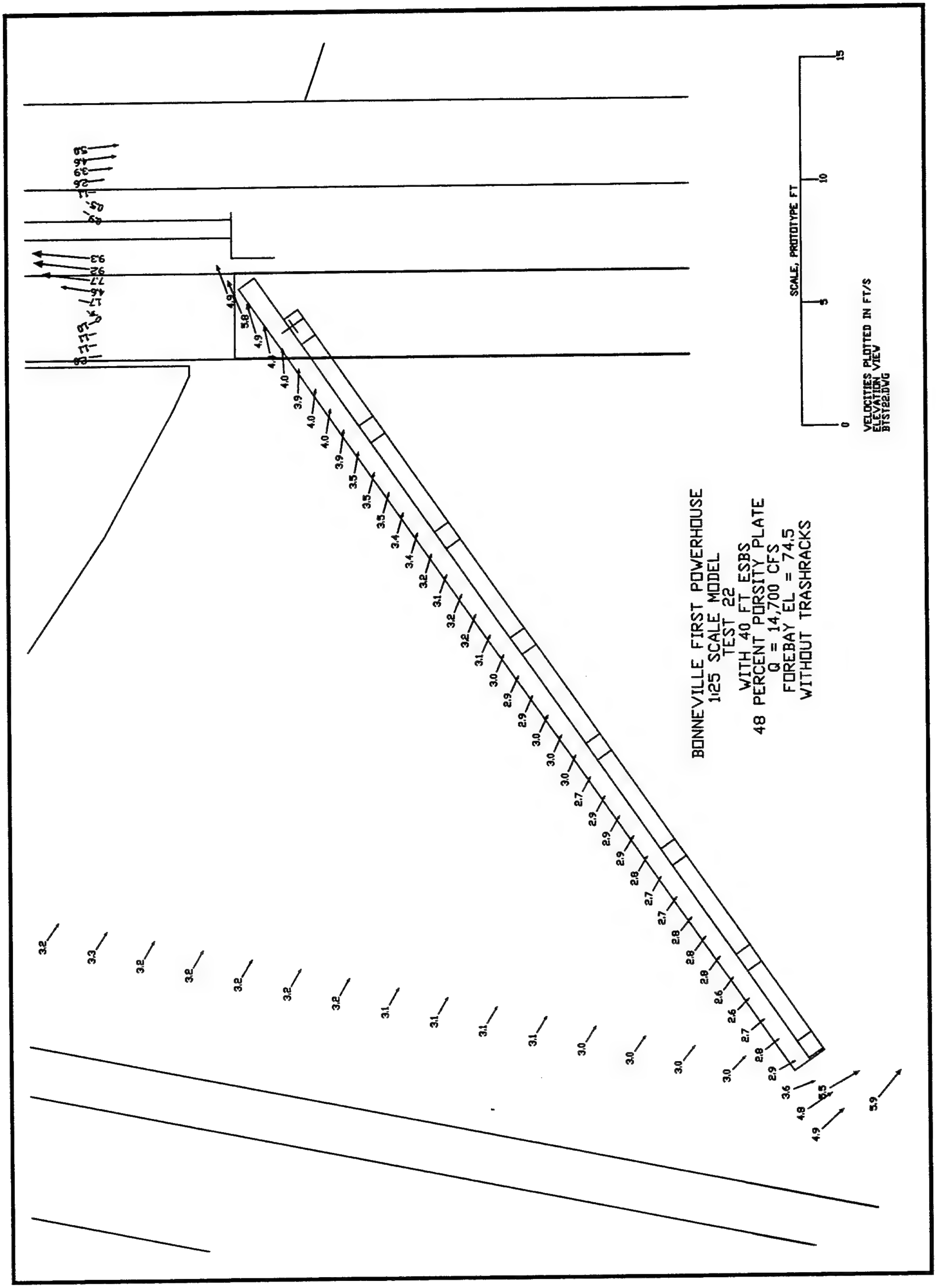
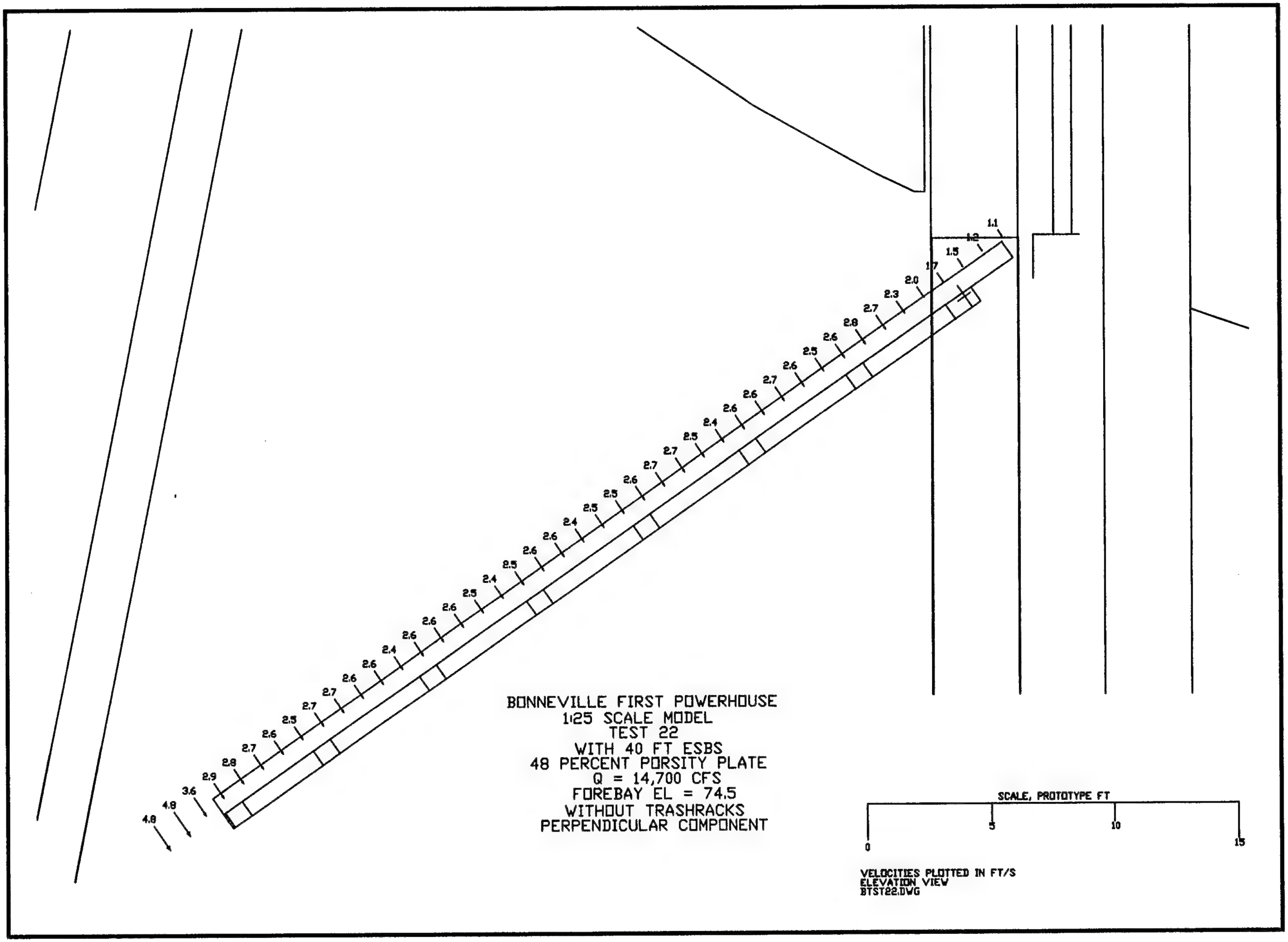
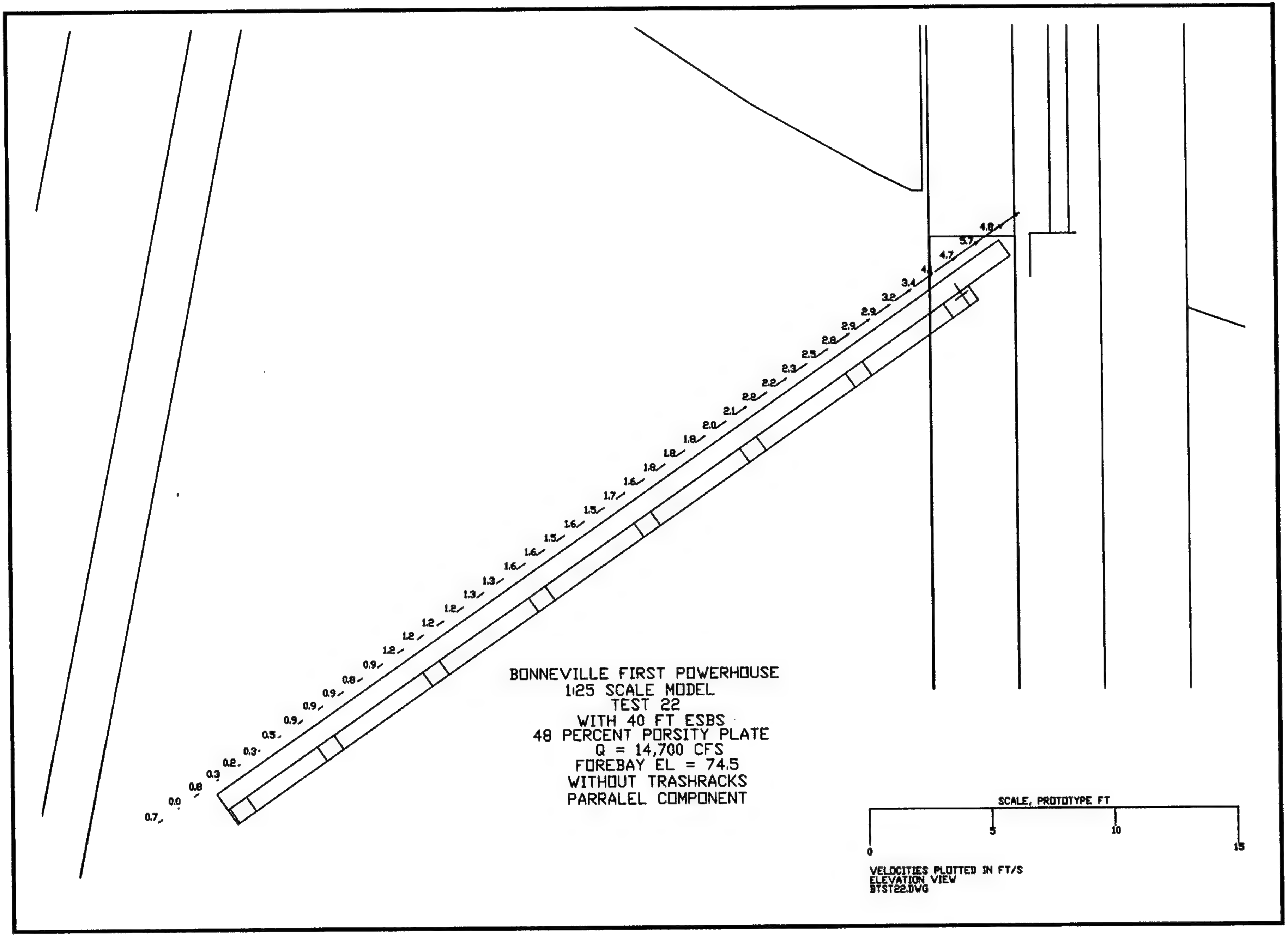
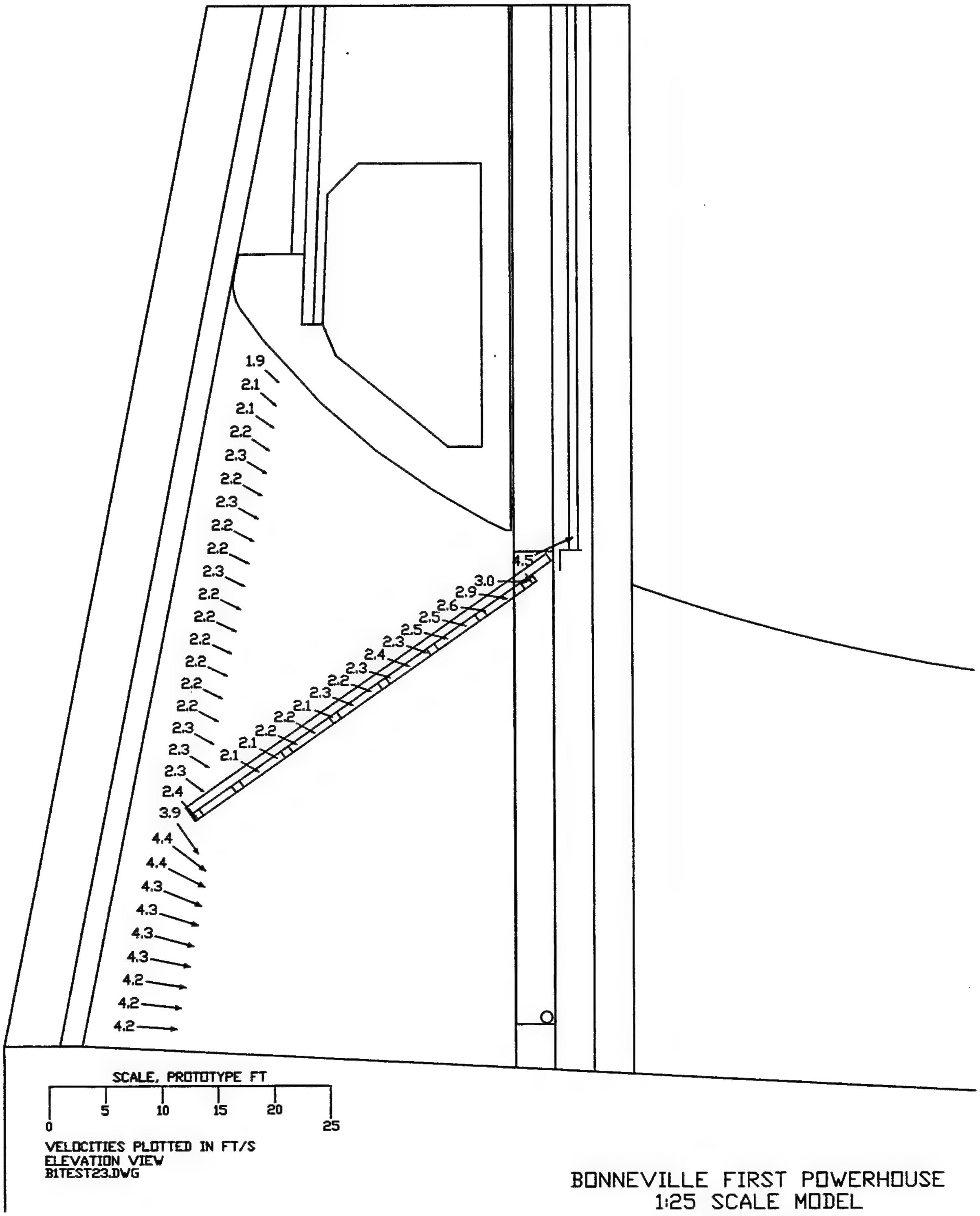

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 22
WITH 40 FT ESBS
48 PERCENT PORSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
SCALE, PROTOTYPE FT
0
5
10
15
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST22.DWG

PLATE 7


BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 22
WITH 40 FT ESBS
48 PERCENT PORSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
PERPENDICULAR COMPONENT
SCALE, PROTOTYPE FT
0
5
10
15
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST22.DWG
1.1
1.2
1.5
1.7
2.0
2.3
2.7
2.8
2.6
2.5
2.6
2.7
2.6
2.6
2.4
2.5
2.7
2.7
2.6
2.5
2.5
2.4
2.6
2.6
2.5
2.4
2.5
2.6
2.6
2.6
2.4
2.6
2.6
2.7
2.7
2.5
2.6
2.7
2.8
2.9
3.6
4.8
4.8


BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 22
WITH 40 FT ESBS
48 PERCENT PORSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
PARRALEL COMPONENT
SCALE, PROTOTYPE FT
0
5
10
15
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST22.DWG



BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 23
WITH 40 FT ESBS
48 PERCENT POROSITY PLATE
Q = 11,200 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS

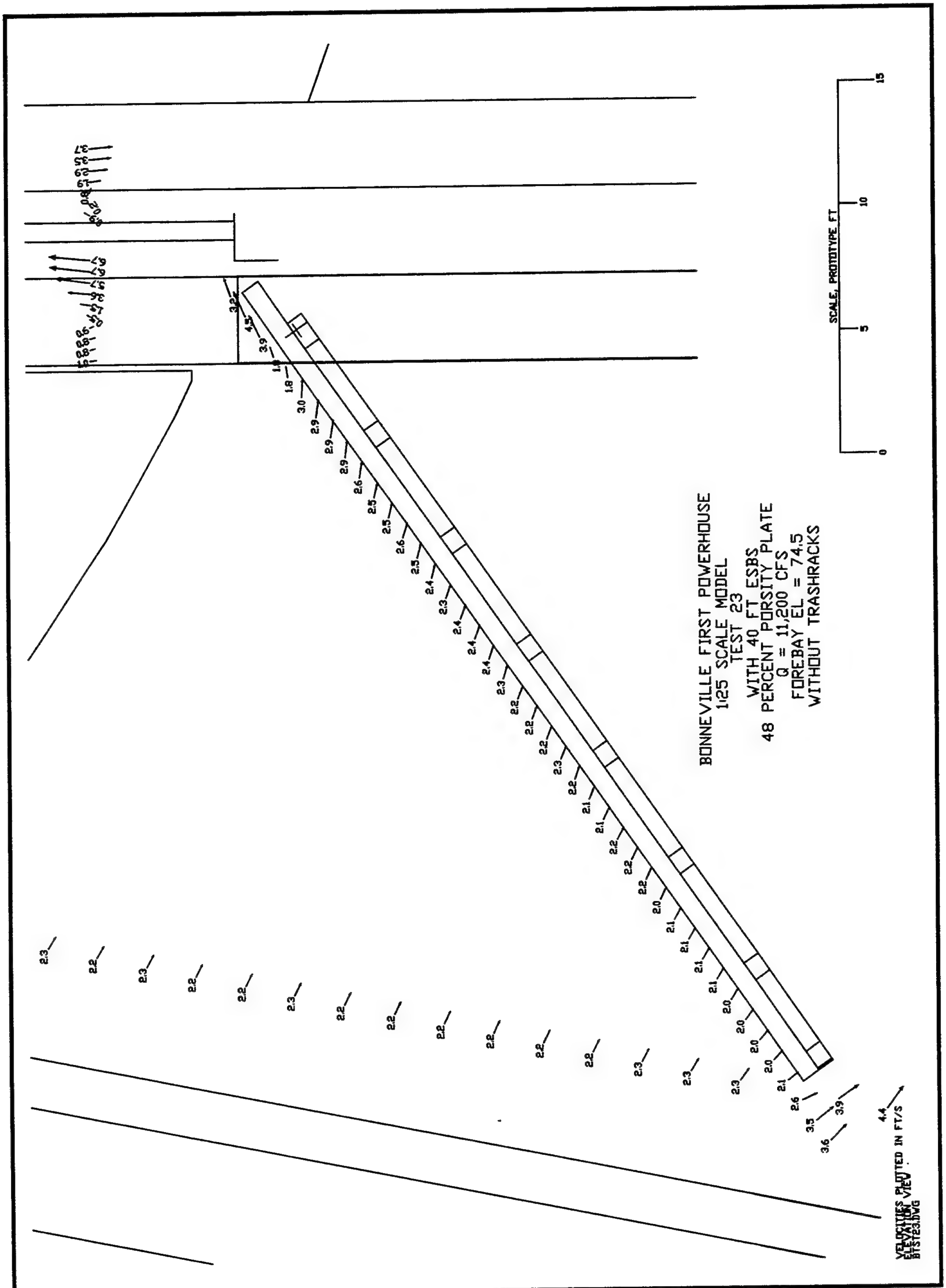
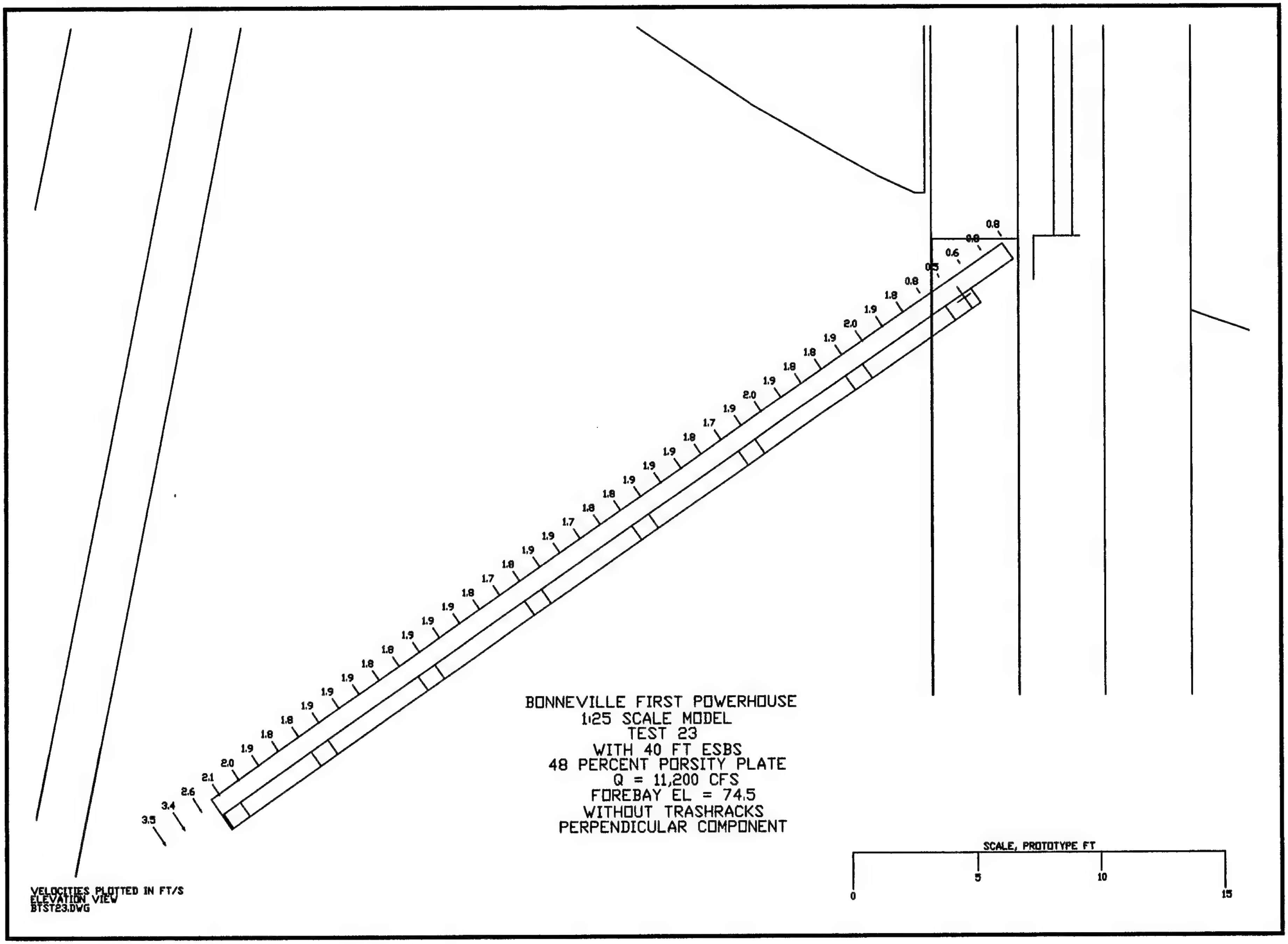
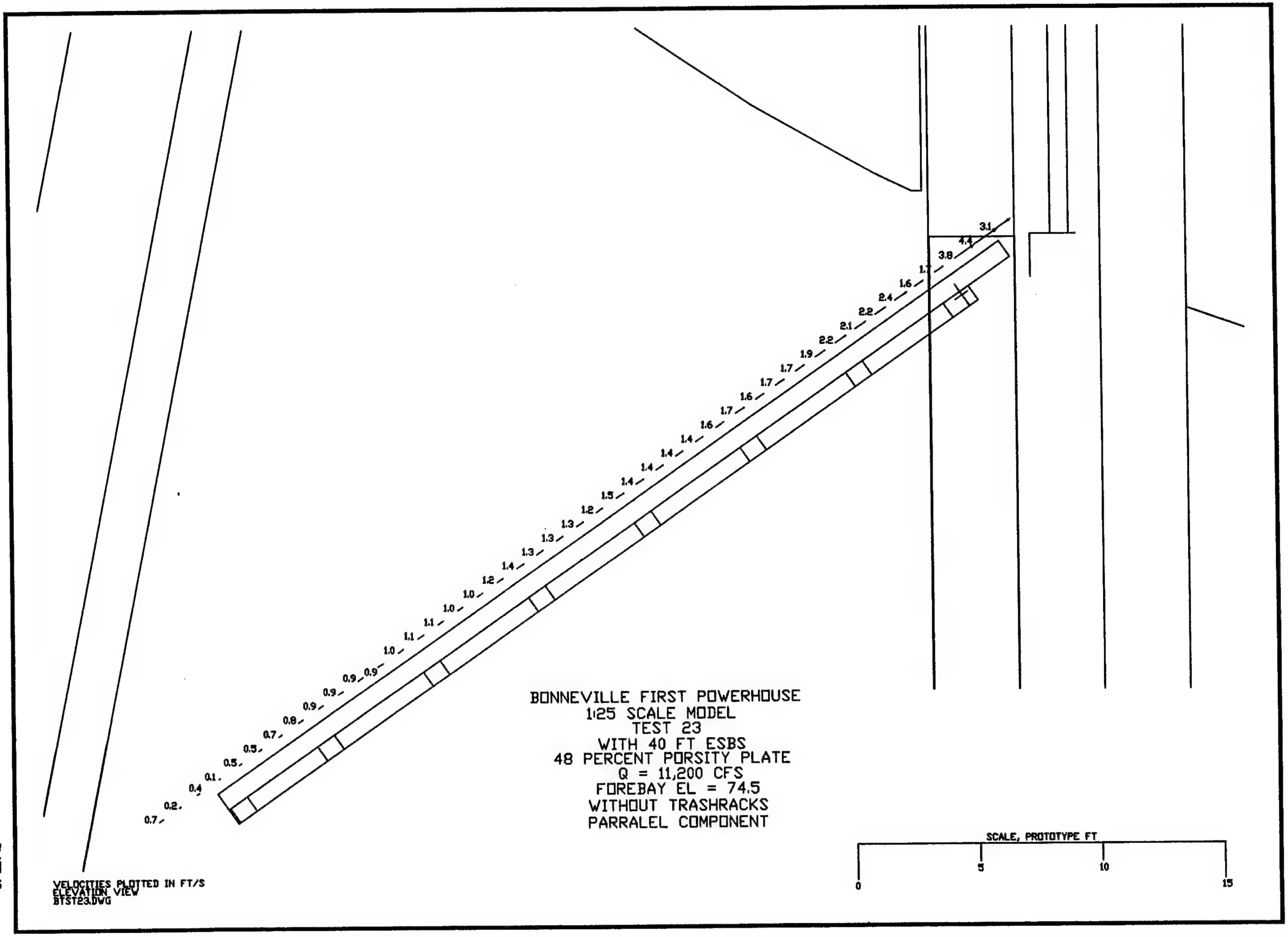
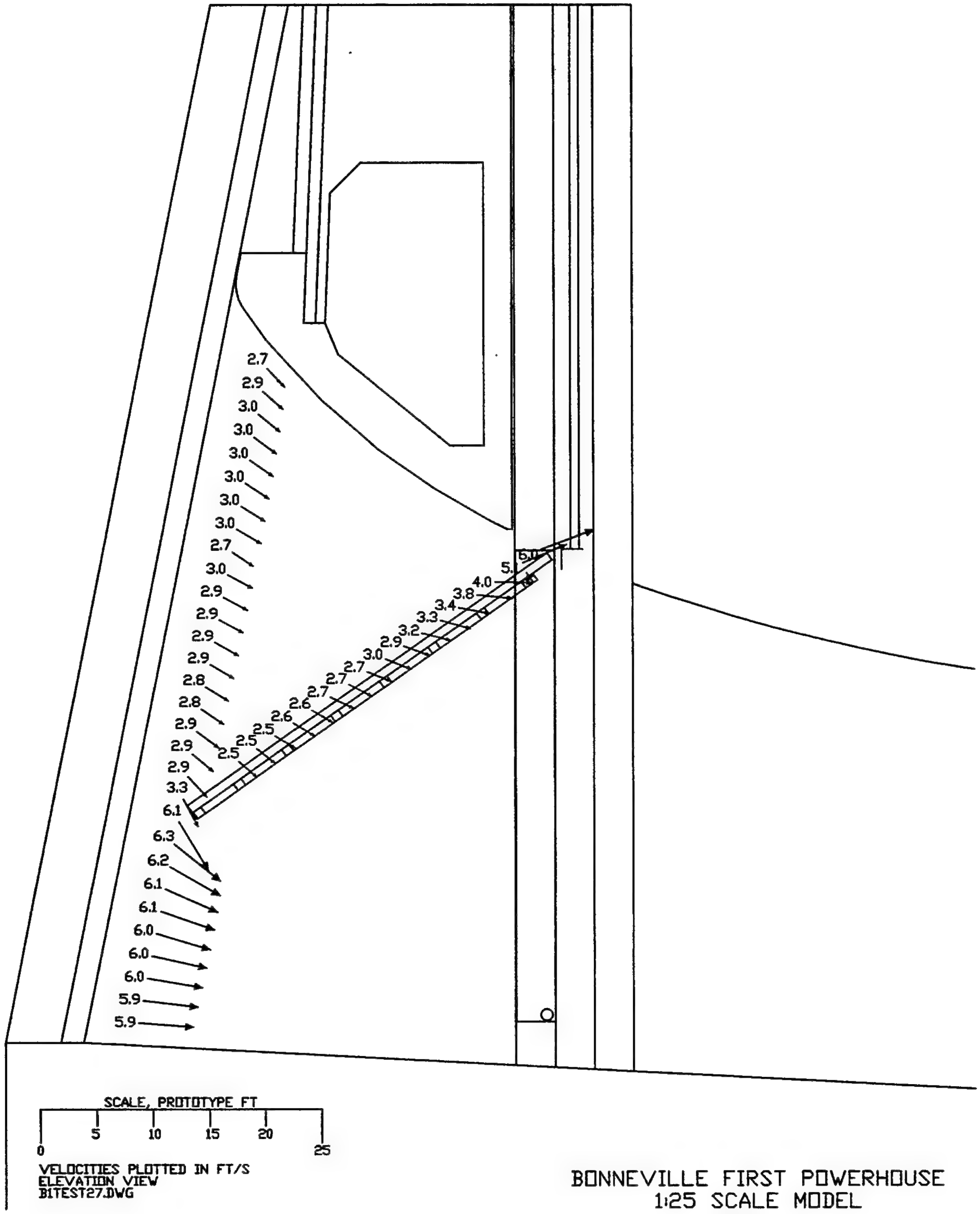

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 23
WITH 40 FT ESBS
48 PERCENT PORSITY PLATE
Q = 11,200 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
SCALE, PROTOTYPE FT
0
5
10
15
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST23.DWG

PLATE 11

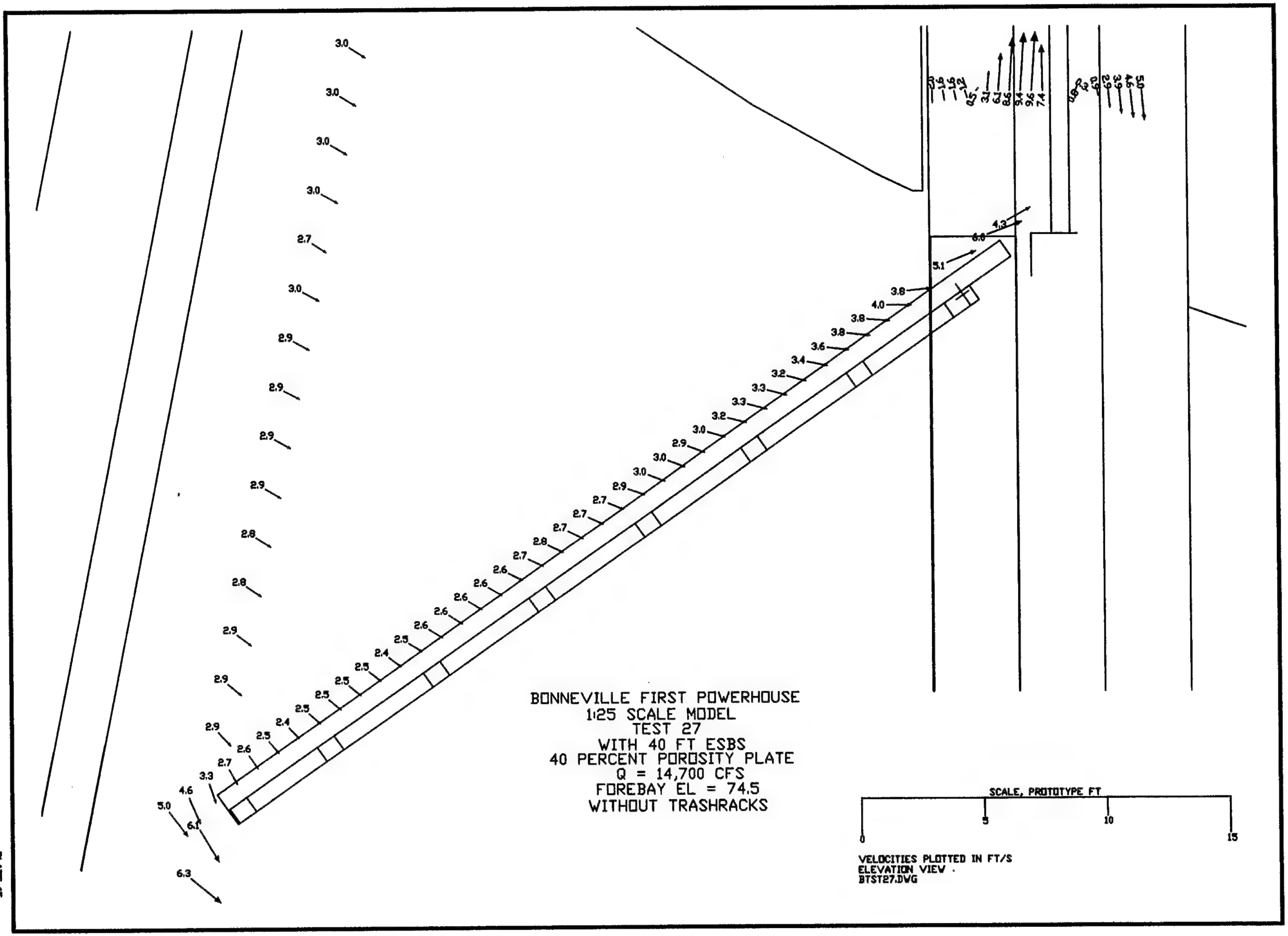


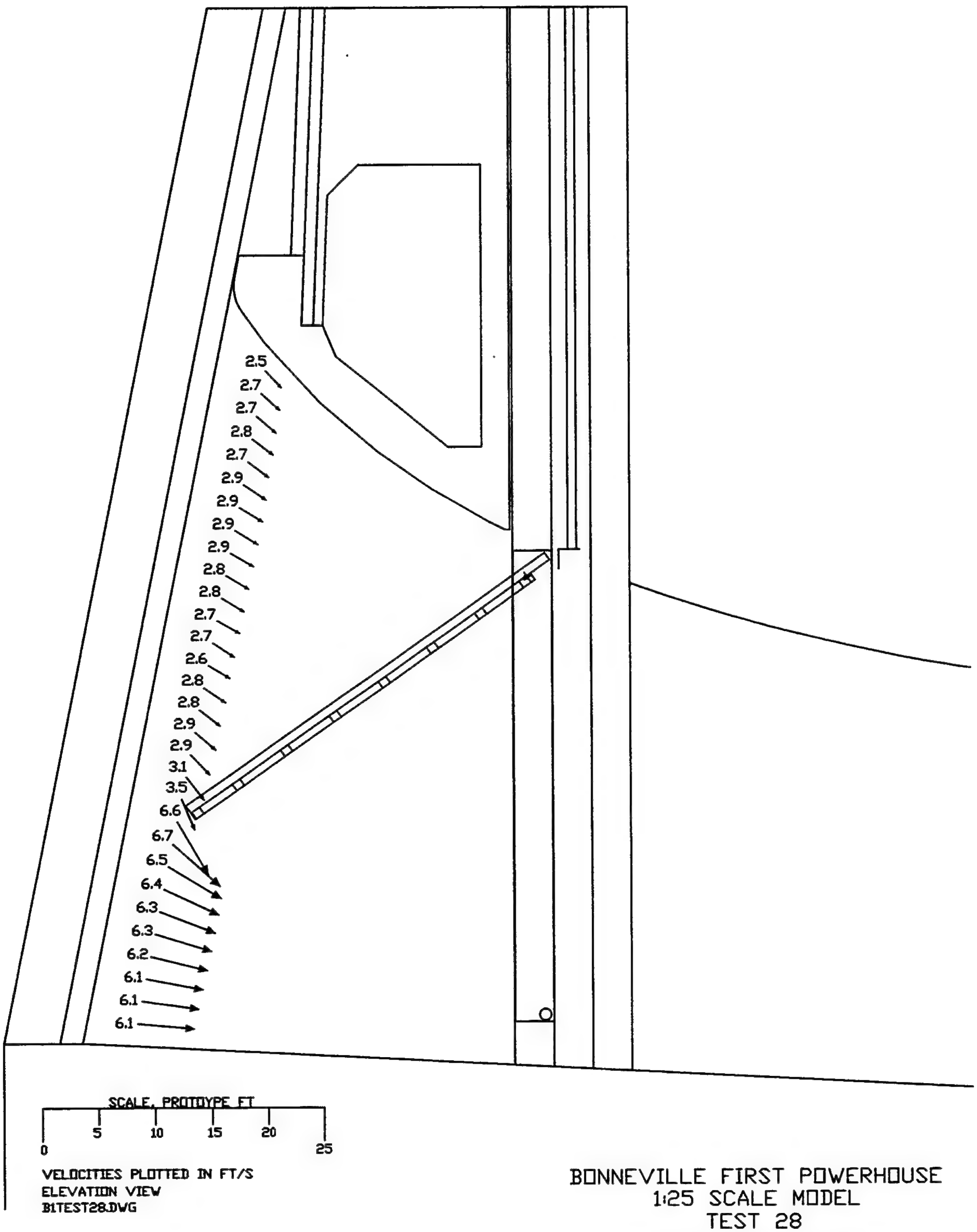
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 23
WITH 40 FT ESBS
48 PERCENT PORSITY PLATE
Q = 11,200 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
PERPENDICULAR COMPONENT
SCALE, PROTOTYPE FT
0
5
10
15
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST23.DWG
3.5
3.4
2.6
2.1
2.0
1.9
1.8
1.8
1.9
1.9
1.8
1.9
1.8
1.9
1.9
1.8
1.7
1.8
1.9
1.9
1.7
1.8
1.8
1.9
1.9
1.9
1.8
1.7
1.9
2.0
1.9
1.8
1.8
1.9
2.0
1.9
1.8
0.8
0.5
0.6
0.8
0.8


BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 23
WITH 40 FT ESBS
48 PERCENT PORSITY PLATE
Q = 11,200 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
PARRALEL COMPONENT
SCALE, PROTOTYPE FT
0
5
10
15
3.1
4.4
3.8
1.7
1.6
2.4
2.2
2.1
2.2
1.9
1.7
1.7
1.6
1.7
1.6
1.4
1.4
1.4
1.4
1.5
1.2
1.3
1.3
1.3
1.4
1.2
1.0
1.0
1.1
1.1
1.0
0.9
0.9
0.9
0.9
0.8
0.7
0.5
0.5
0.1
0.4
0.2
0.7
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST23.DWG

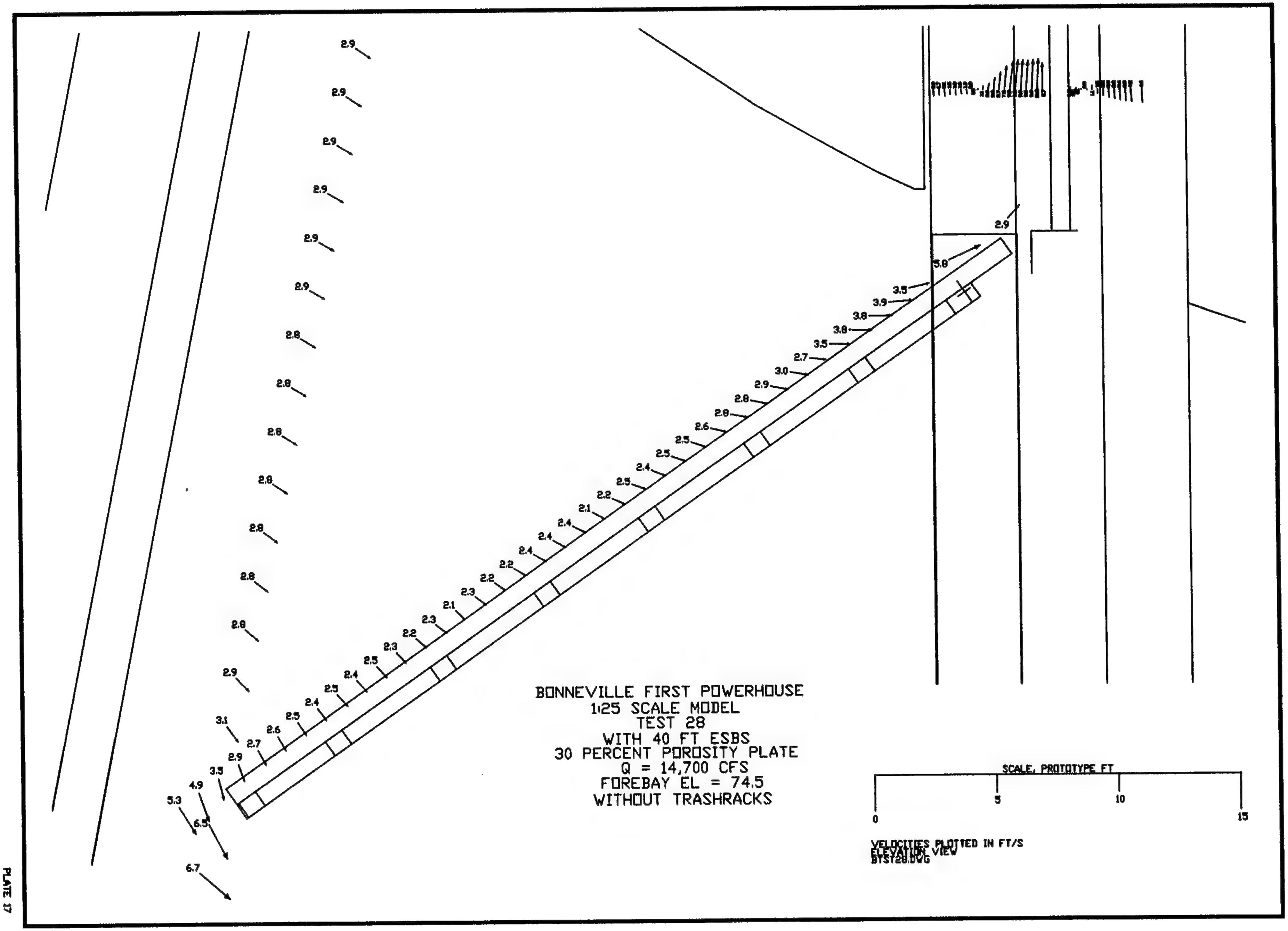


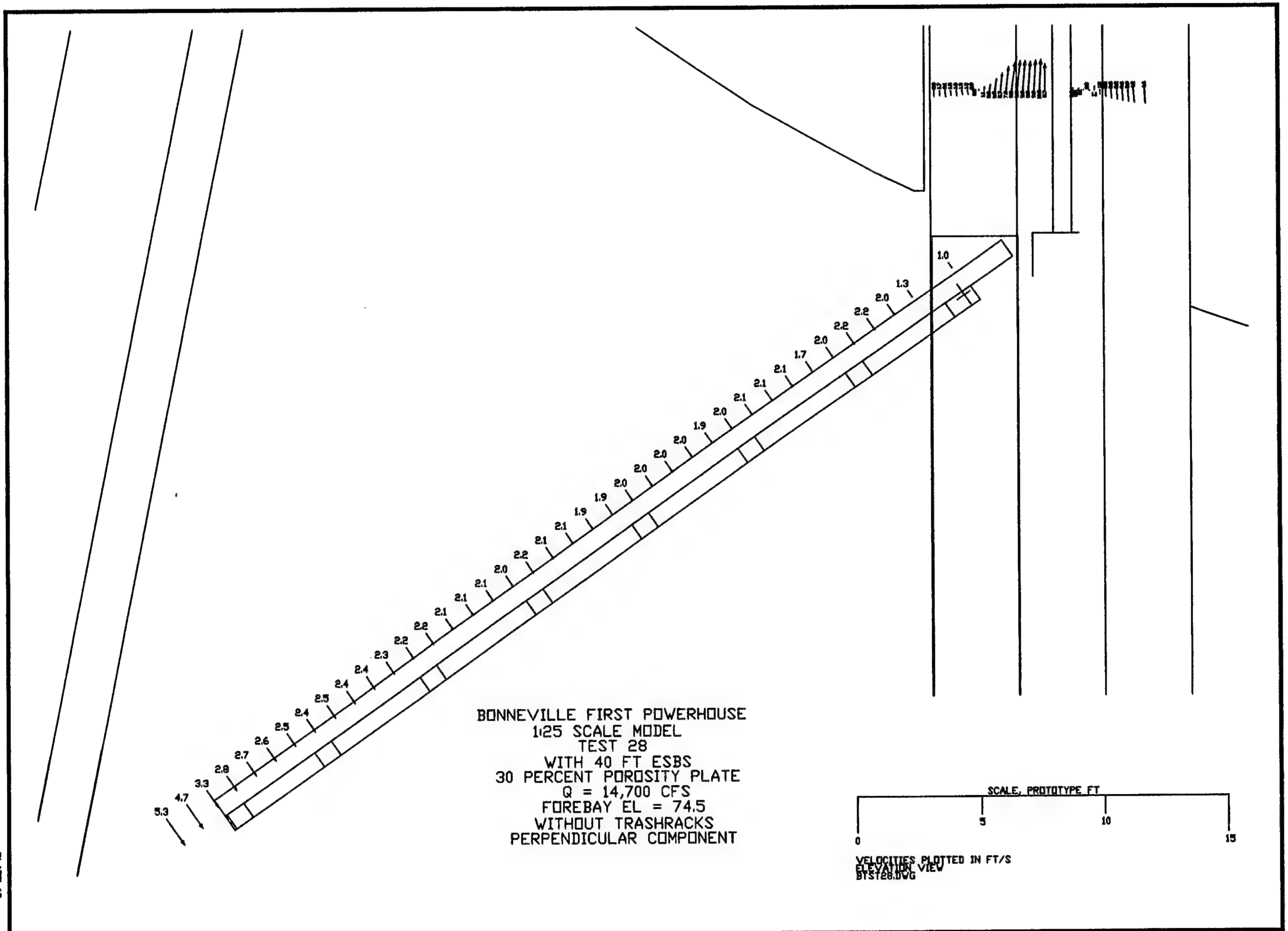
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 27
WITH 40 FT ESBS
40 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS

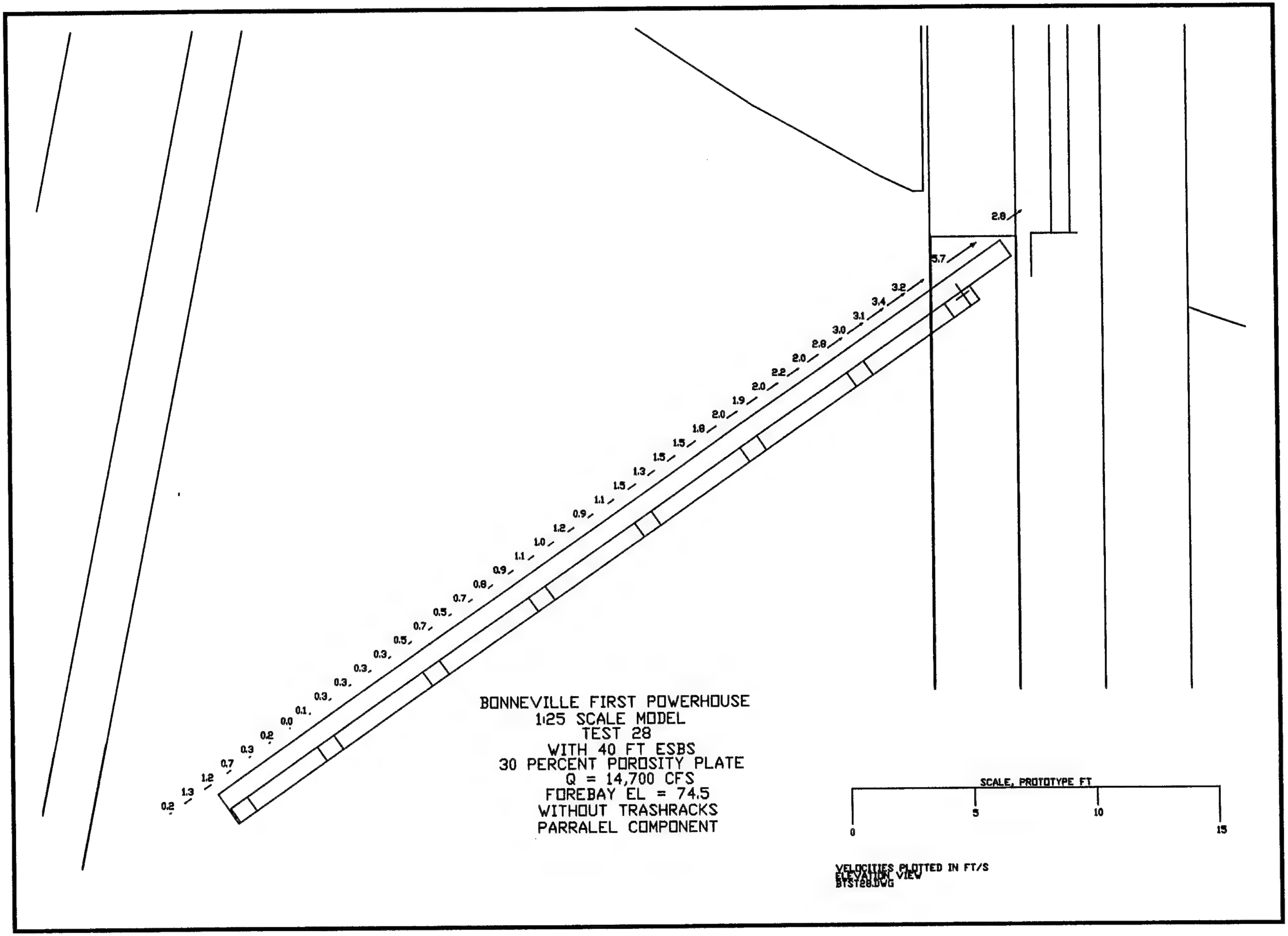

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 27
WITH 40 FT ESBS
40 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
SCALE, PROTOTYPE FT
0
5
10
15
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST27.DWG

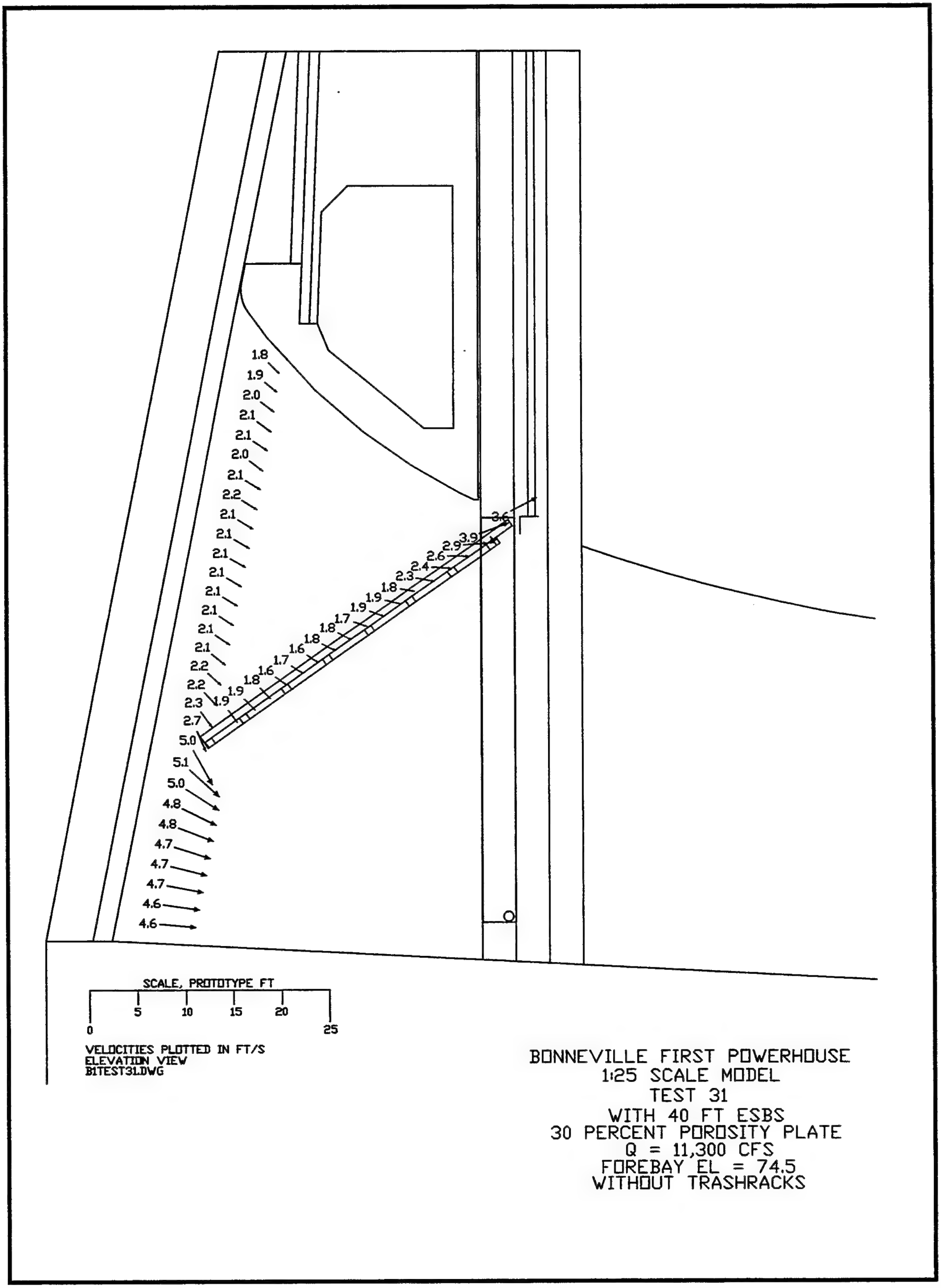


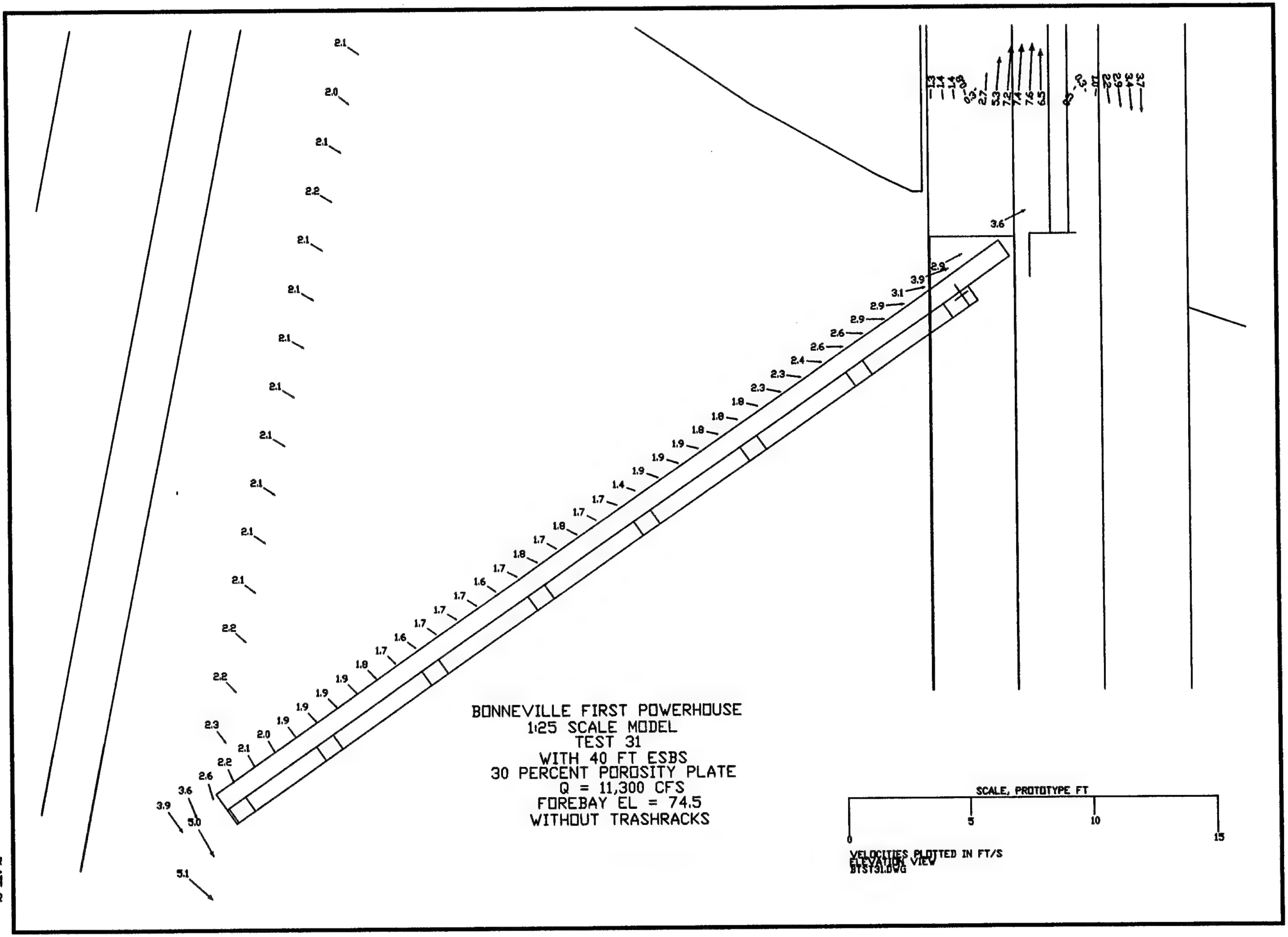
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 28
WITH 40 FT ESBS
30 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
INTERCEPT RETAKE

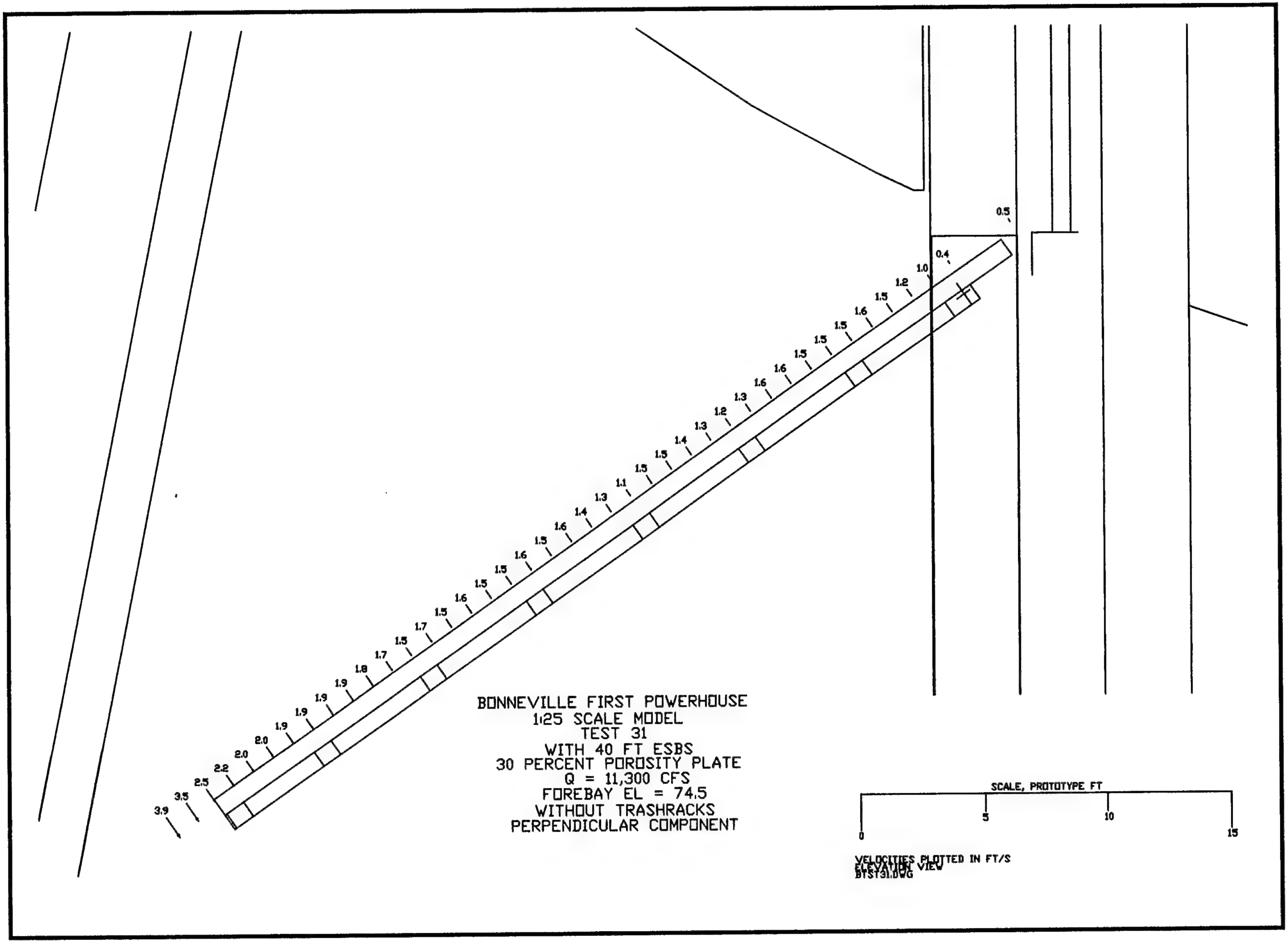

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 28
WITH 40 FT ESBS
30 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
SCALE, PROTOTYPE FT
0
5
10
15
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST28.DWG


BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 28
WITH 40 FT ESBS
30 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
PERPENDICULAR COMPONENT
1.0
1.3
2.0
2.2
2.2
2.0
1.7
2.1
2.1
2.1
2.0
1.9
2.0
2.0
2.0
2.0
1.9
1.9
2.1
2.1
2.2
2.0
2.1
2.1
2.1
2.2
2.2
2.3
2.4
2.4
2.5
2.4
2.5
2.6
2.7
2.8
3.3
4.7
5.3
SCALE, PROTOTYPE FT
0
5
10
15
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST28.DWG

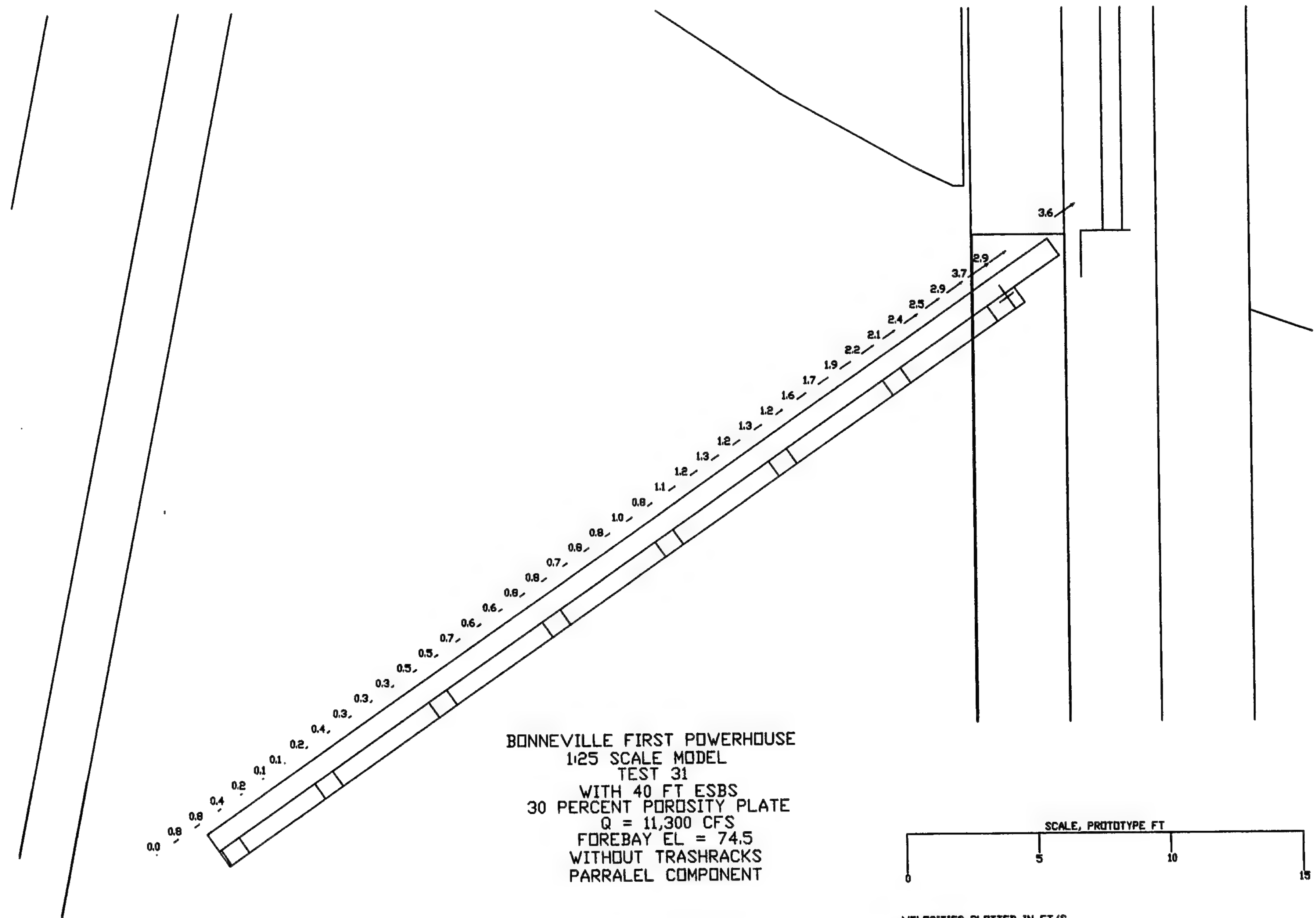

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 28
WITH 40 FT ESBS
30 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
PARRALEL COMPONENT
SCALE, PROTOTYPE FT
0
5
10
15
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST28.DWG
2.8
5.7
3.2
3.4
3.1
3.0
2.8
2.0
2.2
2.0
1.9
2.0
1.8
1.5
1.5
1.3
1.5
1.1
0.9
1.2
1.0
1.1
0.9
0.8
0.7
0.5
0.7
0.5
0.3
0.3
0.3
0.3
0.1
0.0
0.2
0.3
0.7
1.2
1.3
0.2


1.8
1.9
2.0
2.1
2.1
2.0
2.1
2.2
2.1
2.1
2.1
2.1
2.1
2.1
2.1
2.1
2.2
2.2
2.3
2.7
5.0
5.1
5.0
4.8
4.8
4.7
4.7
4.7
4.6
4.6
1.9
1.9
1.8
1.6
1.7
1.6
1.8
1.8
1.7
1.9
1.9
1.8
2.3
2.4
2.6
2.9
3.9
3.6
SCALE, PROTOTYPE FT
0
5
10
15
20
25
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST31.DWG
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 31
WITH 40 FT ESBS
30 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS


BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 31
WITH 40 FT ESBS
30 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
SCALE, PROTOTYPE FT
0
5
10
15
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST31.DWG



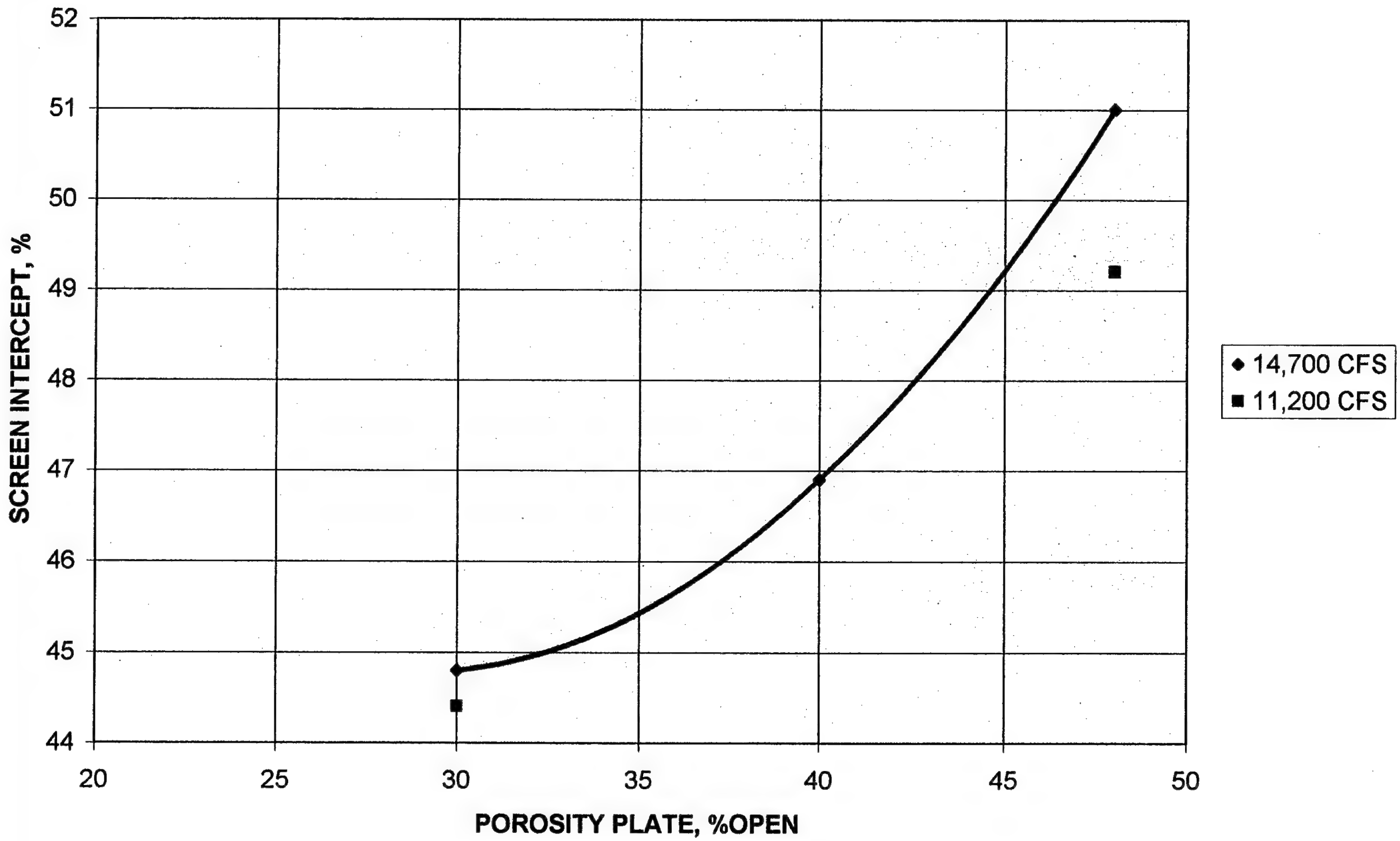
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 31
WITH 40 FT ESBS
30 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
PERPENDICULAR COMPONENT

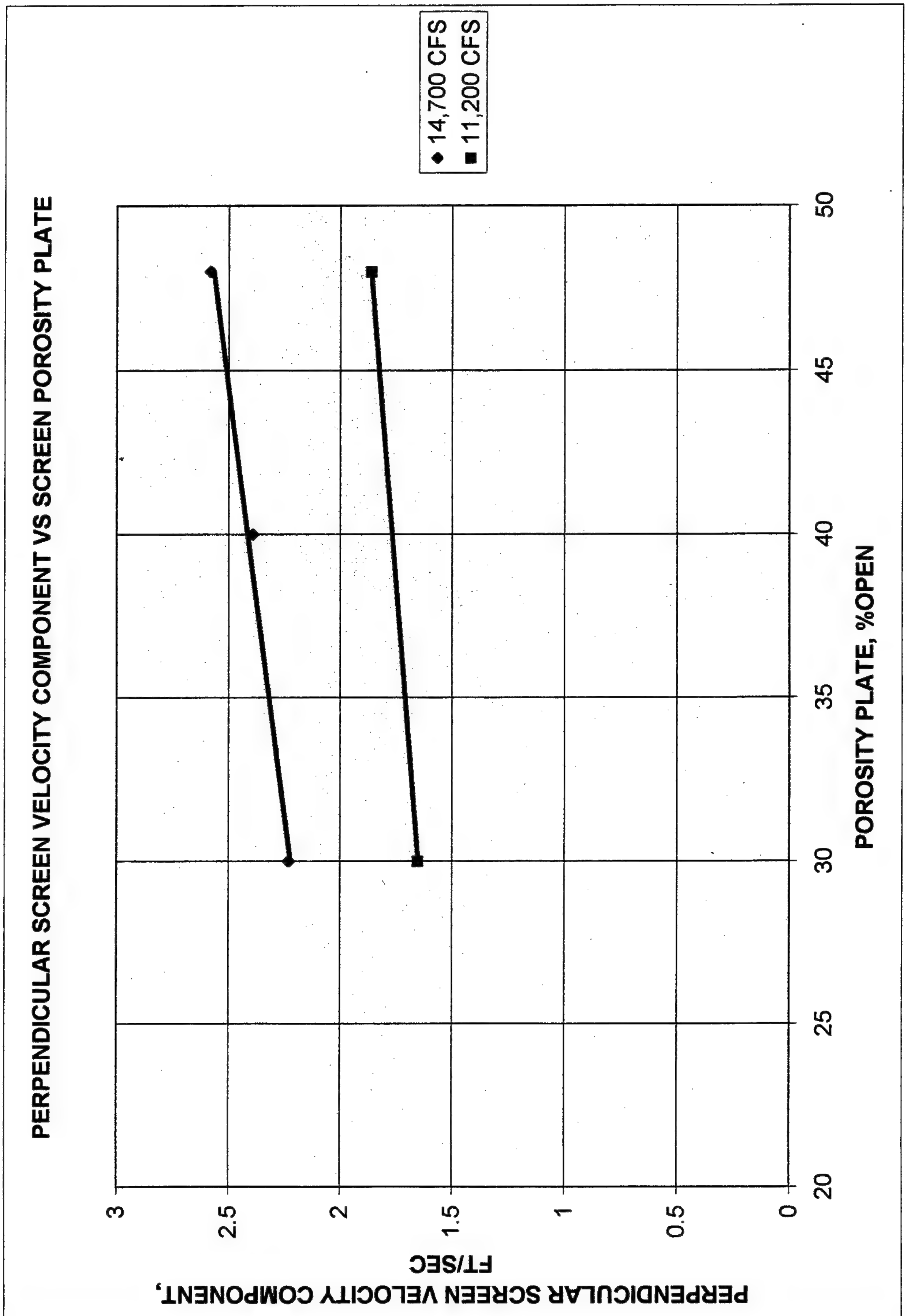


BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 31
WITH 40 FT ESBS
30 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
PARRALEL COMPONENT

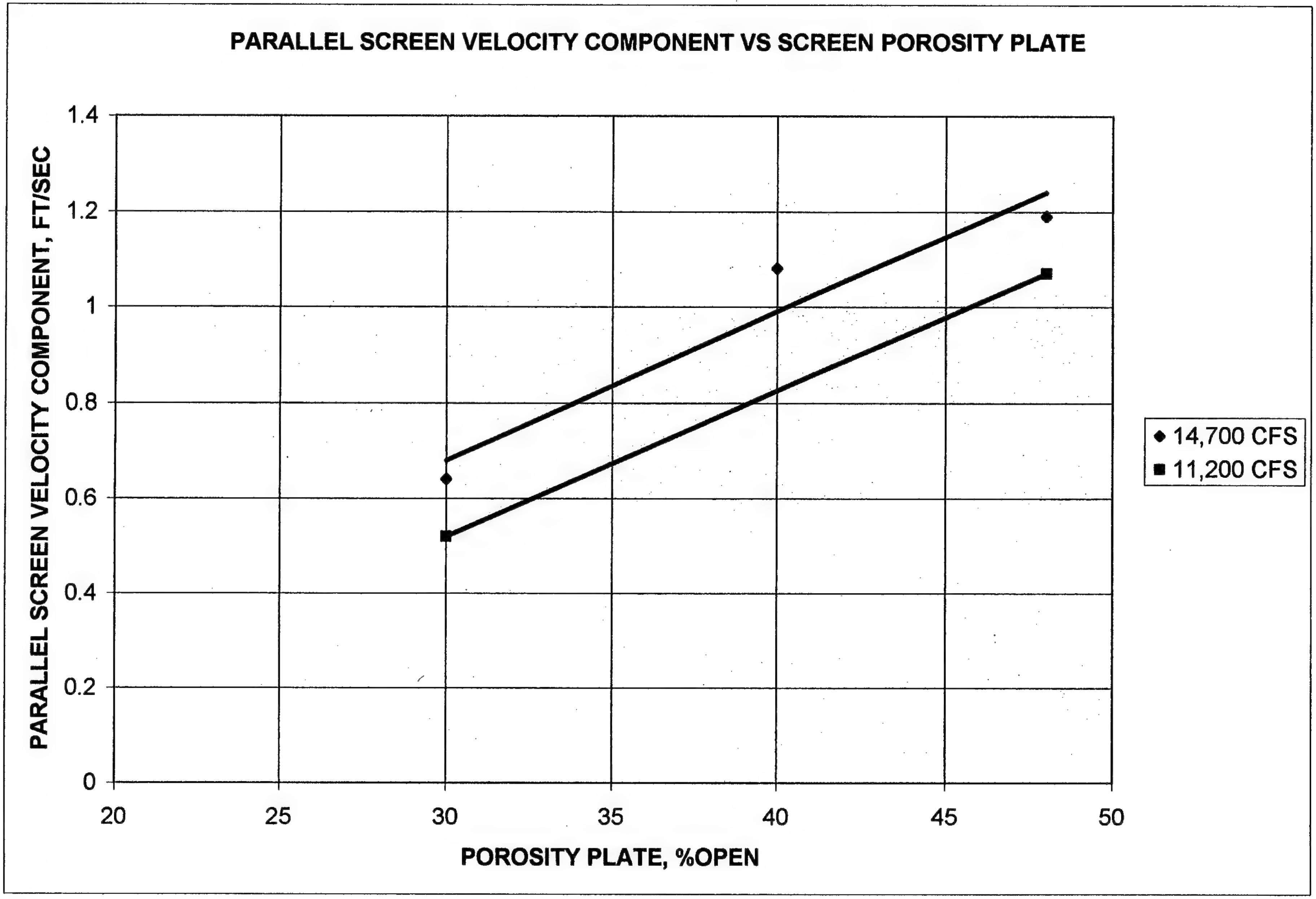
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST31.DWG

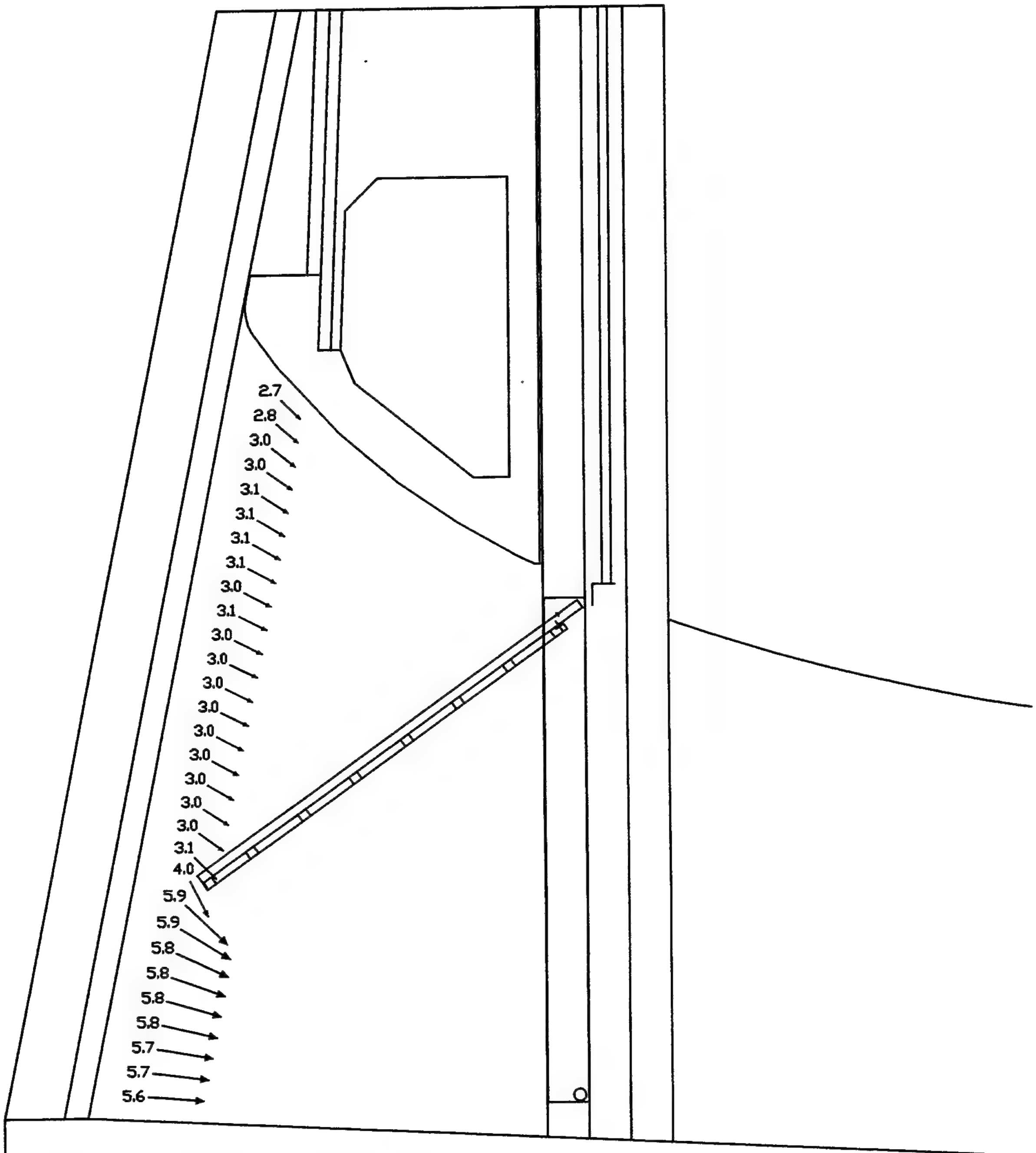
PERCENT FLOW INTERCEPT VS SCREEN POROSITY PLATE





PERPENDICULAR SCREEN VELOCITY COMPONENT VS SCREEN POROSITY PLATE
14,700 CFS
11,200 CFS
PERPENDICULAR SCREEN VELOCITY COMPONENT, FT/SEC
0
0.5
1
1.5
2
2.5
3
POROSITY PLATE, %OPEN
20
25
30
35
40
45
50


PARALLEL SCREEN VELOCITY COMPONENT VS SCREEN POROSITY PLATE
PARALLEL SCREEN VELOCITY COMPONENT, FT/SEC
1.4
1.2
1
0.8
0.6
0.4
0.2
0
20
25
30
35
40
45
50
POROSITY PLATE, %OPEN
14,700 CFS
11,200 CFS



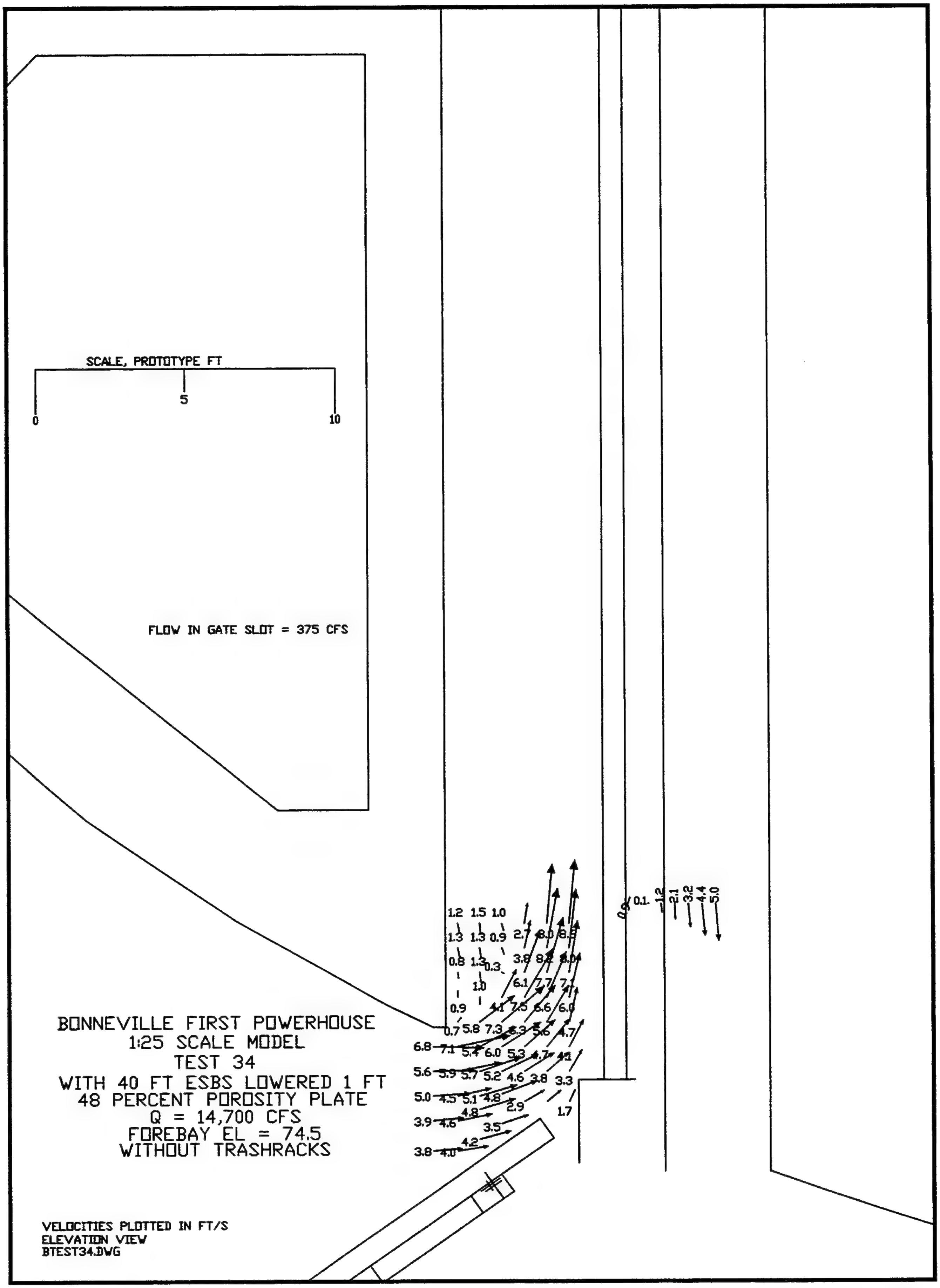
PERCENT FLOW INTERCEPTED BY ESBS = 50.6

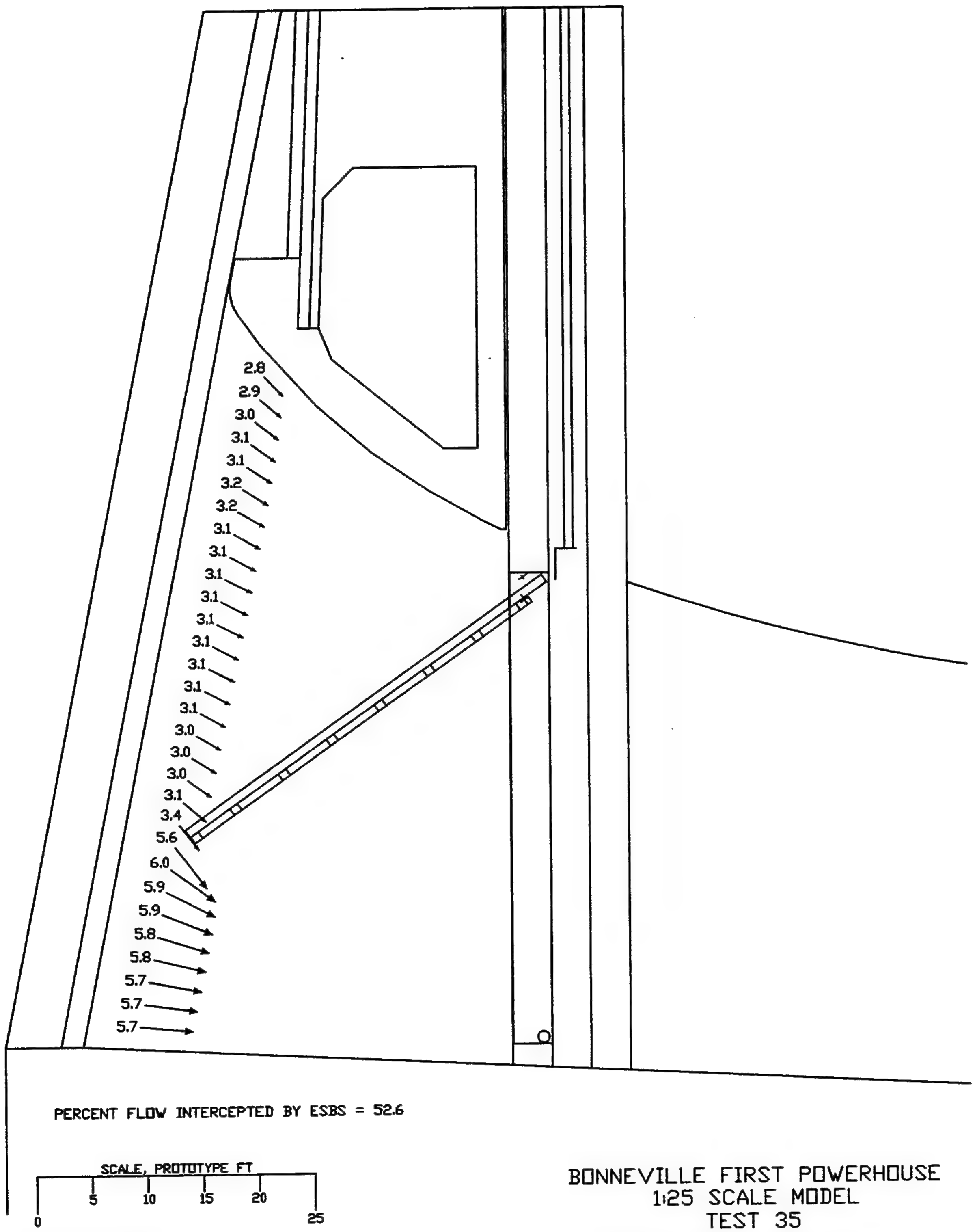
SCALE, PROTOTYPE FT

0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST34.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 34
WITH 40 FT ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS


SCALE, PROTOTYPE FT
0
5
10
FLOW IN GATE SLOT = 375 CFS
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 34
WITH 40 FT ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST34.DWG



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST35.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 35
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS

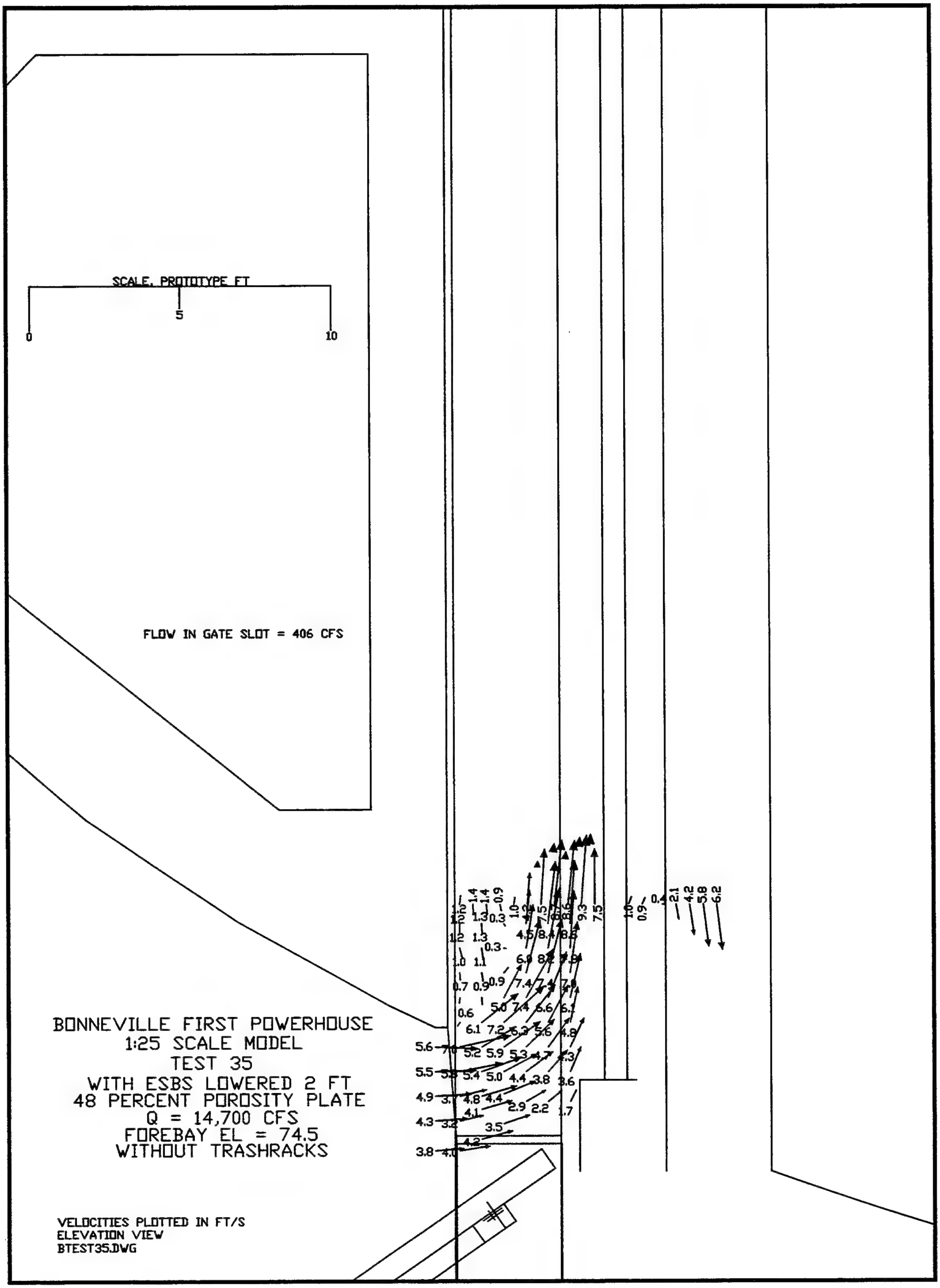

SCALE, PROTOTYPE FT
0
5
10
FLOW IN GATE SLOT = 406 CFS
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 35
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST35.DWG

PLATE 30

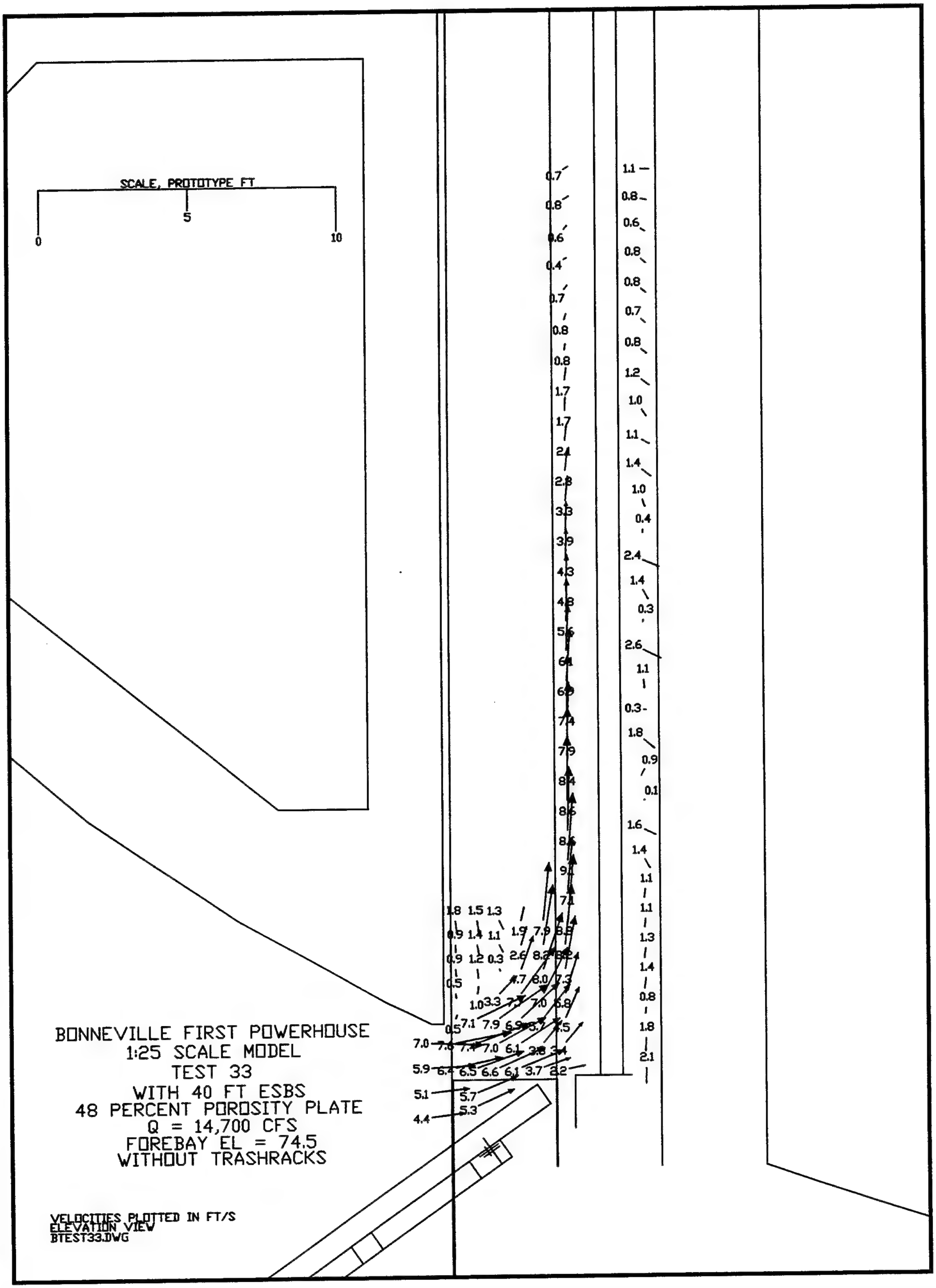
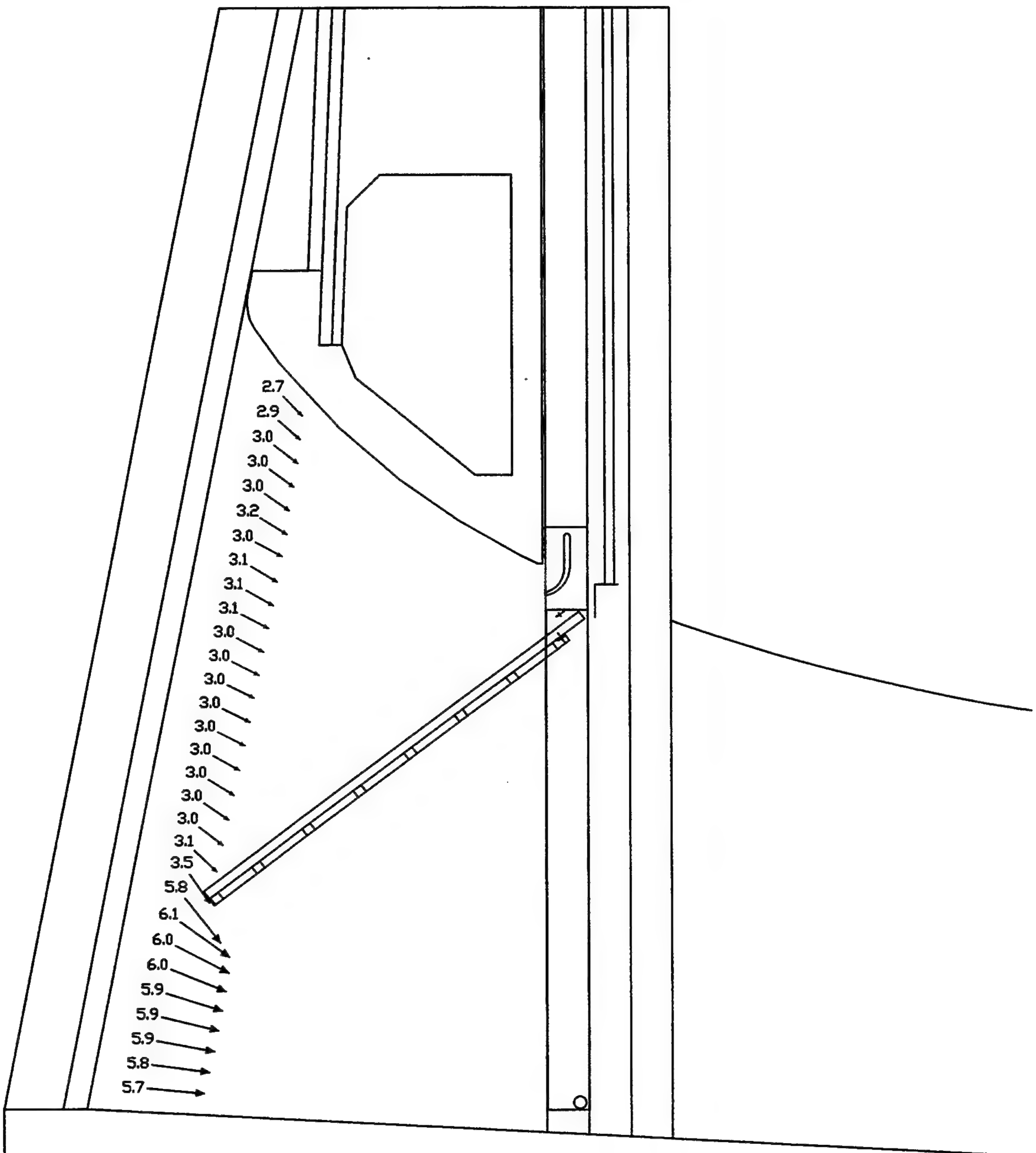

SCALE, PROTOTYPE FT
0
5
10
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 33
WITH 40 FT ESBS
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST33.DWG

PLATE 31



PERCENT FLOW INTERCEPTED BY ESBS = 51.4

SCALE, PROTOTYPE FT

0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST37A.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 37A
WITH ESBS LOWERED 2 FT
48% ESBS @ 55 DEG
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 1 IN PLACE

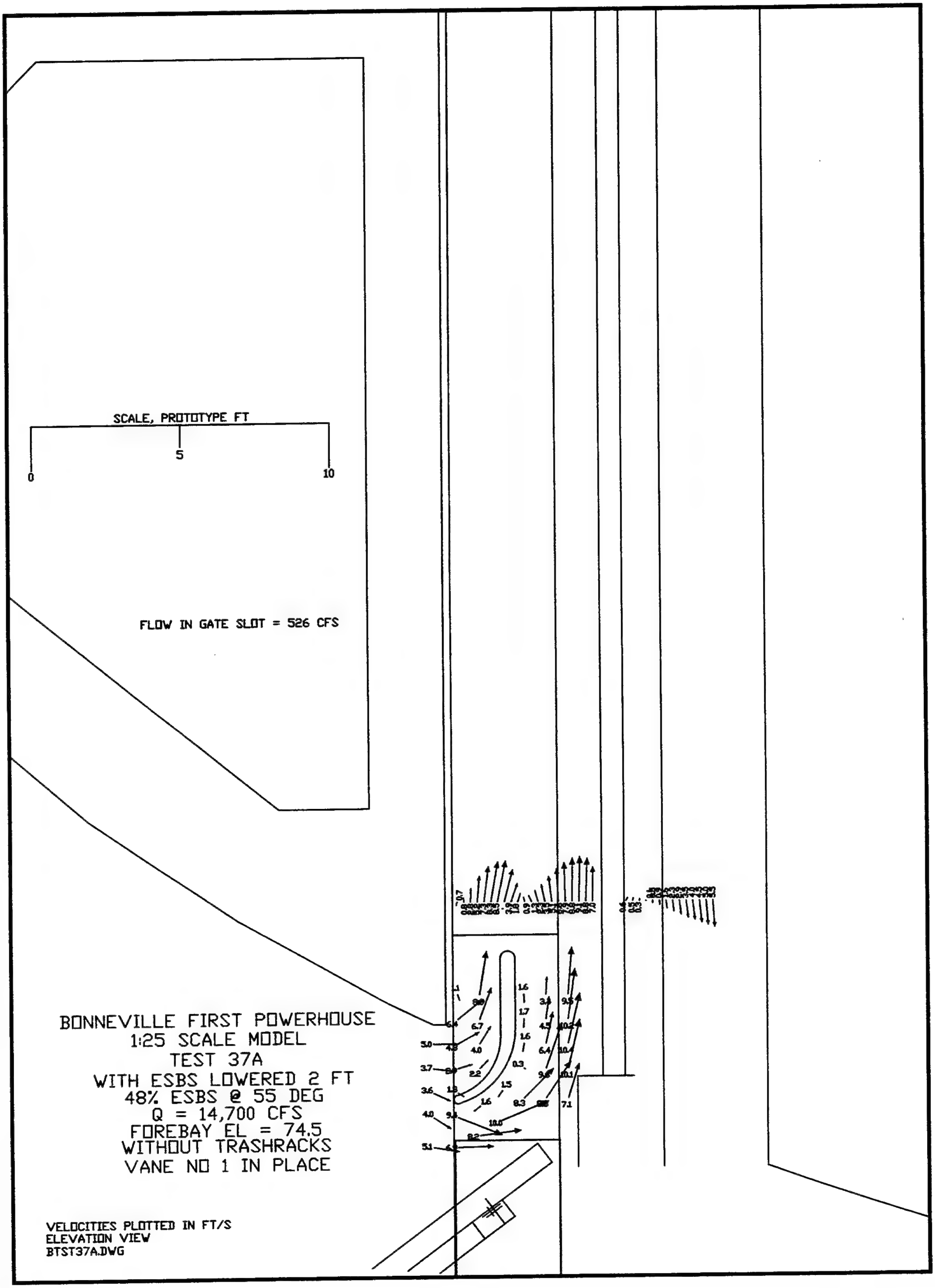
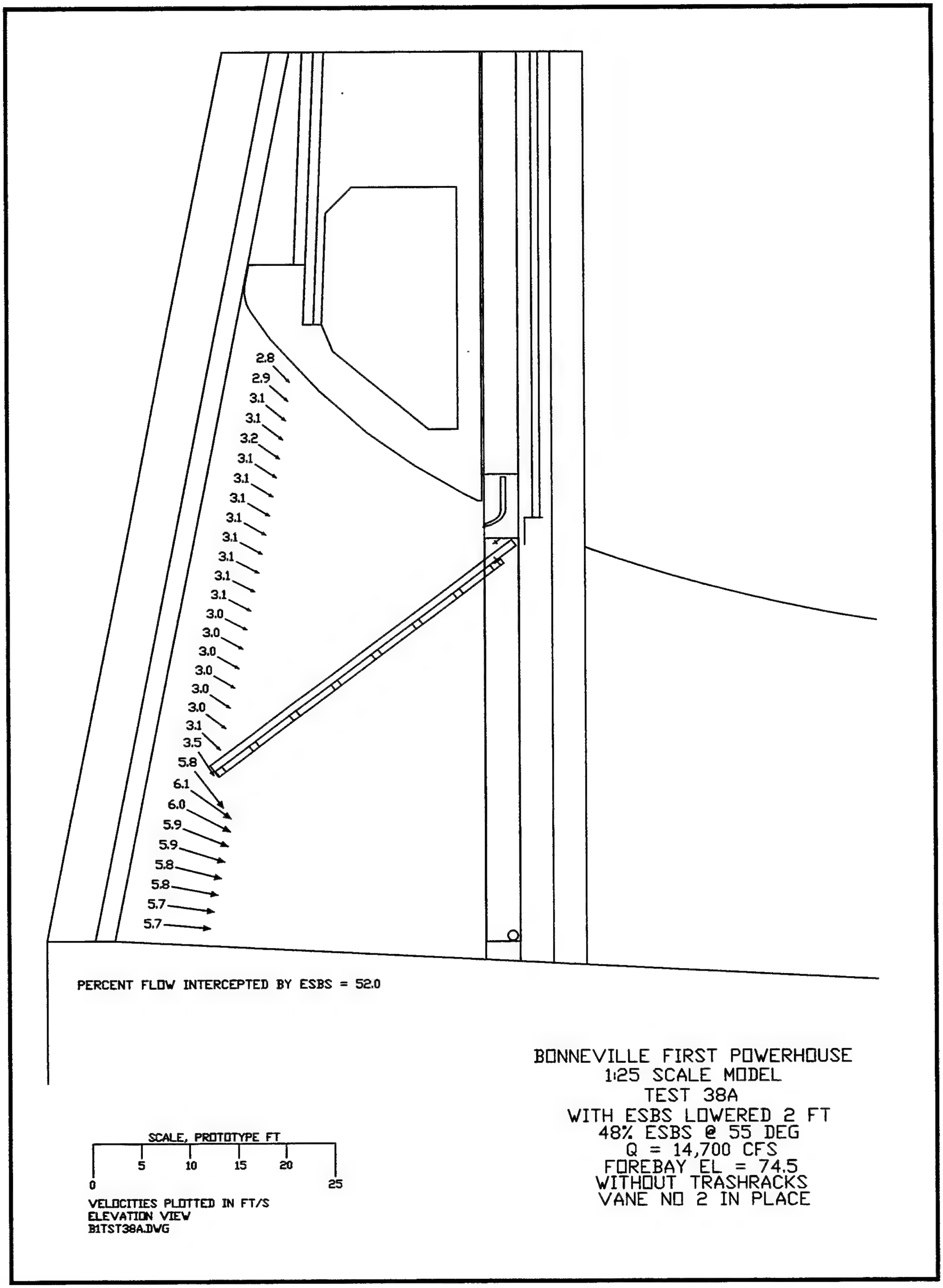

SCALE, PROTOTYPE FT
0
5
10
FLOW IN GATE SLOT = 526 CFS
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 37A
WITH ESBS LOWERED 2 FT
48% ESBS @ 55 DEG
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 1 IN PLACE
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST37A.DWG

PLATE 33


2.8
2.9
3.1
3.1
3.2
3.1
3.1
3.1
3.1
3.1
3.1
3.1
3.1
3.0
3.0
3.0
3.0
3.0
3.0
3.1
3.5
5.8
6.1
6.0
5.9
5.9
5.8
5.8
5.7
5.7
PERCENT FLOW INTERCEPTED BY ESBS = 52.0
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 38A
WITH ESBS LOWERED 2 FT
48% ESBS @ 55 DEG
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 2 IN PLACE
SCALE, PROTOTYPE FT
0
5
10
15
20
25
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TST38A.DWG

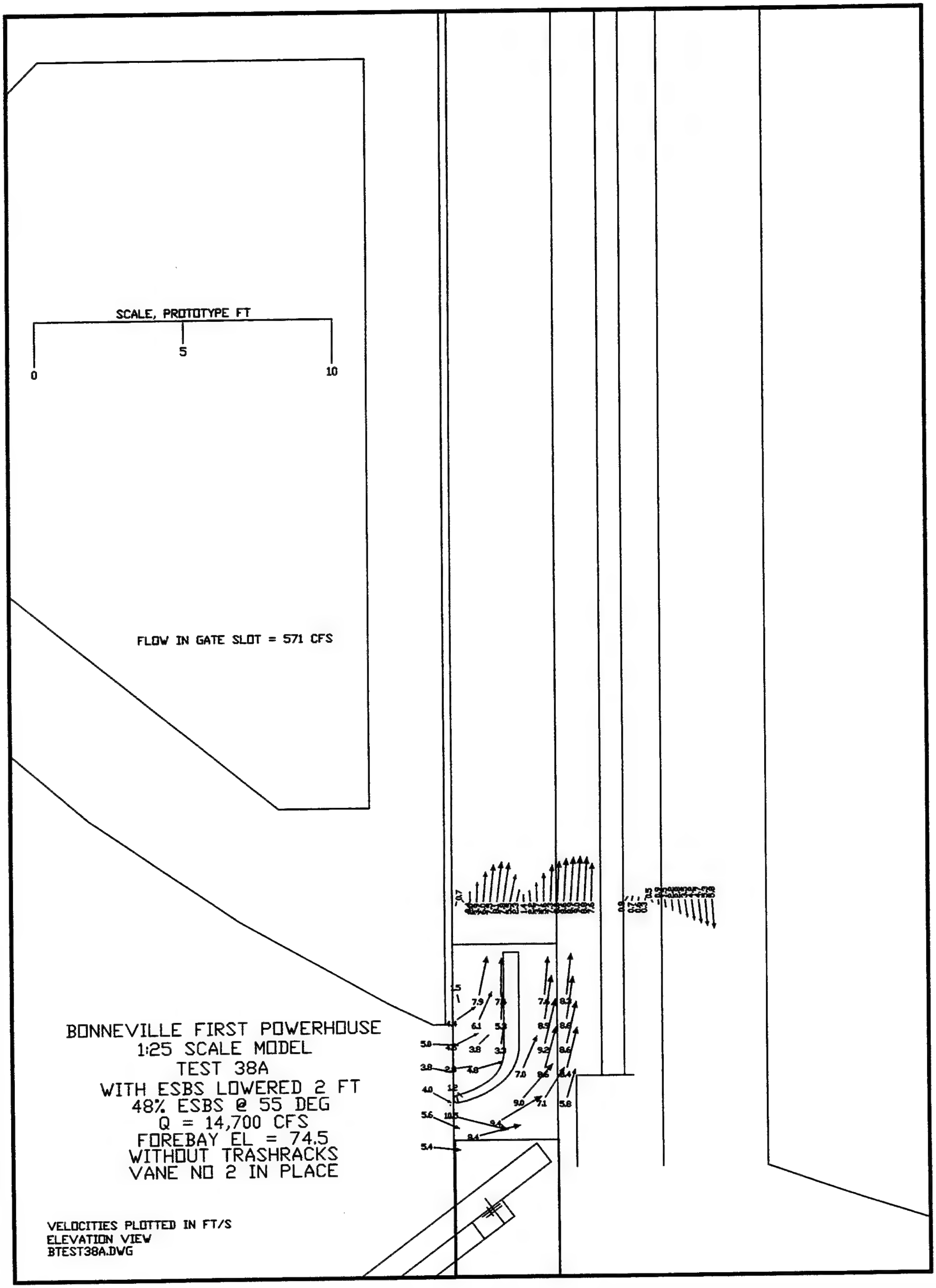
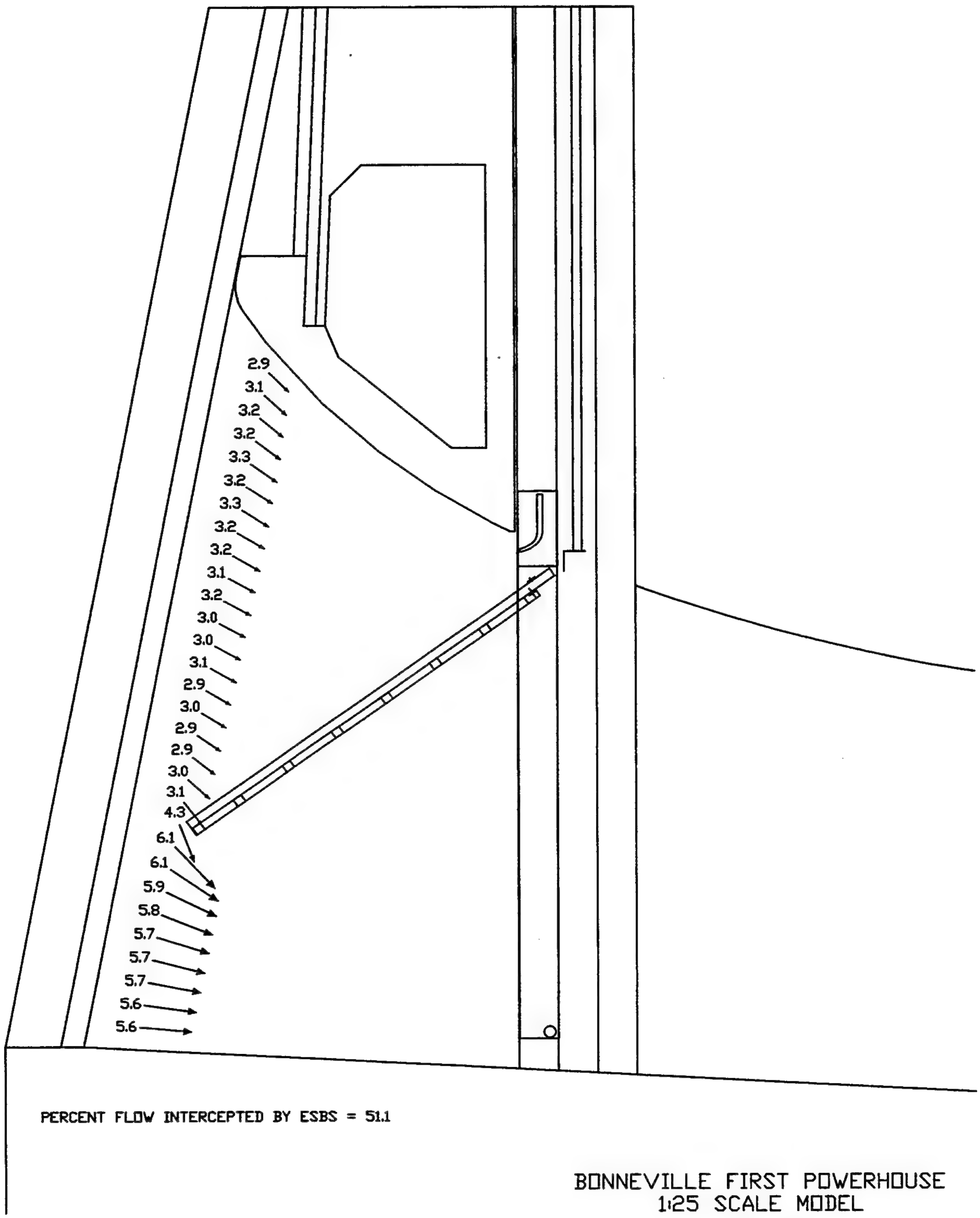

SCALE, PROTOTYPE FT
0
5
10
FLOW IN GATE SLOT = 571 CFS
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 38A
WITH ESBS LOWERED 2 FT
48% ESBS @ 55 DEG
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 2 IN PLACE
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST38A.DWG

PLATE 35



PERCENT FLOW INTERCEPTED BY ESBS = 51.1

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 45
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 2 IN POSITION

SCALE, PROTOTYPE FT

0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST45.DWG

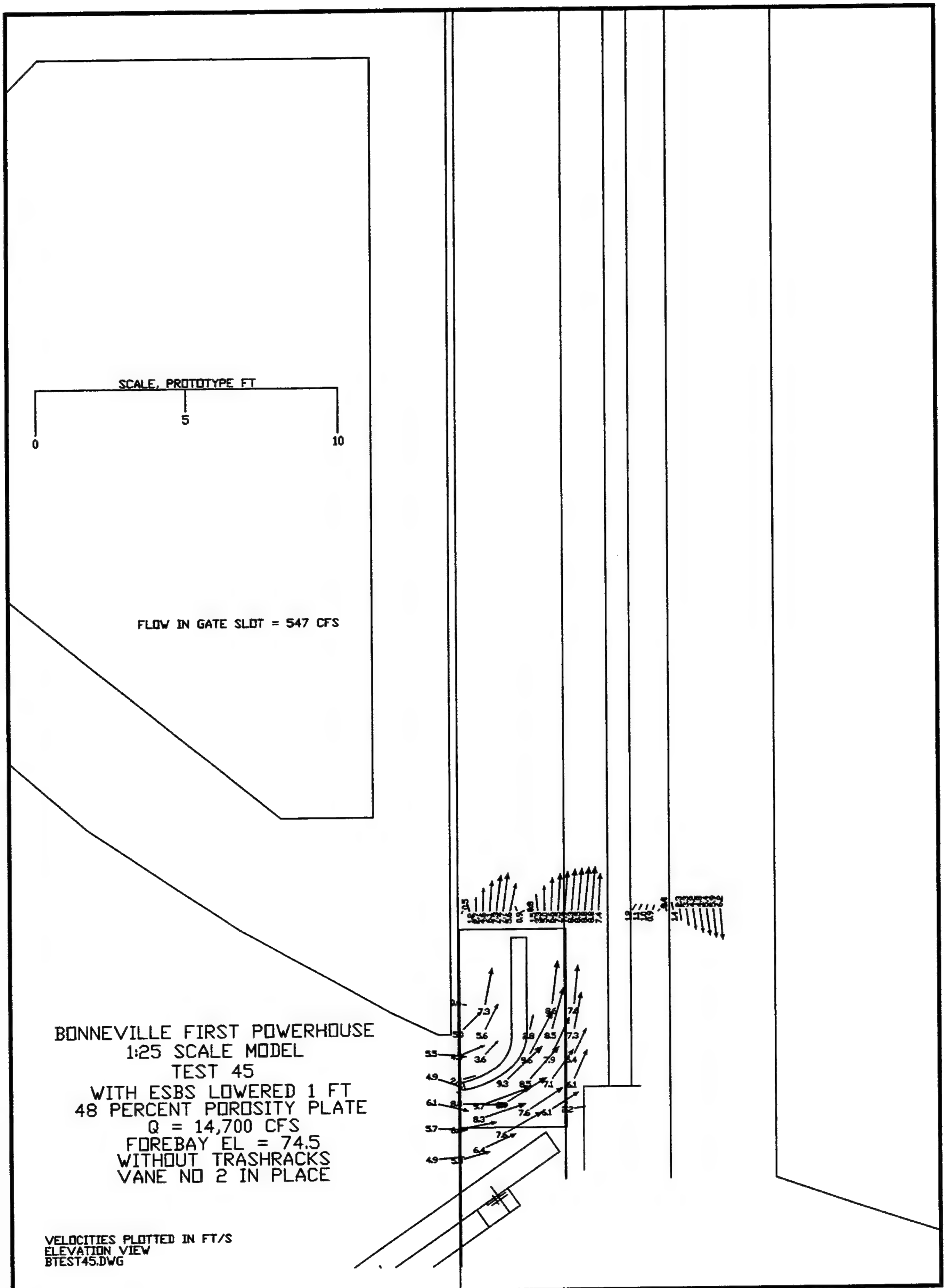
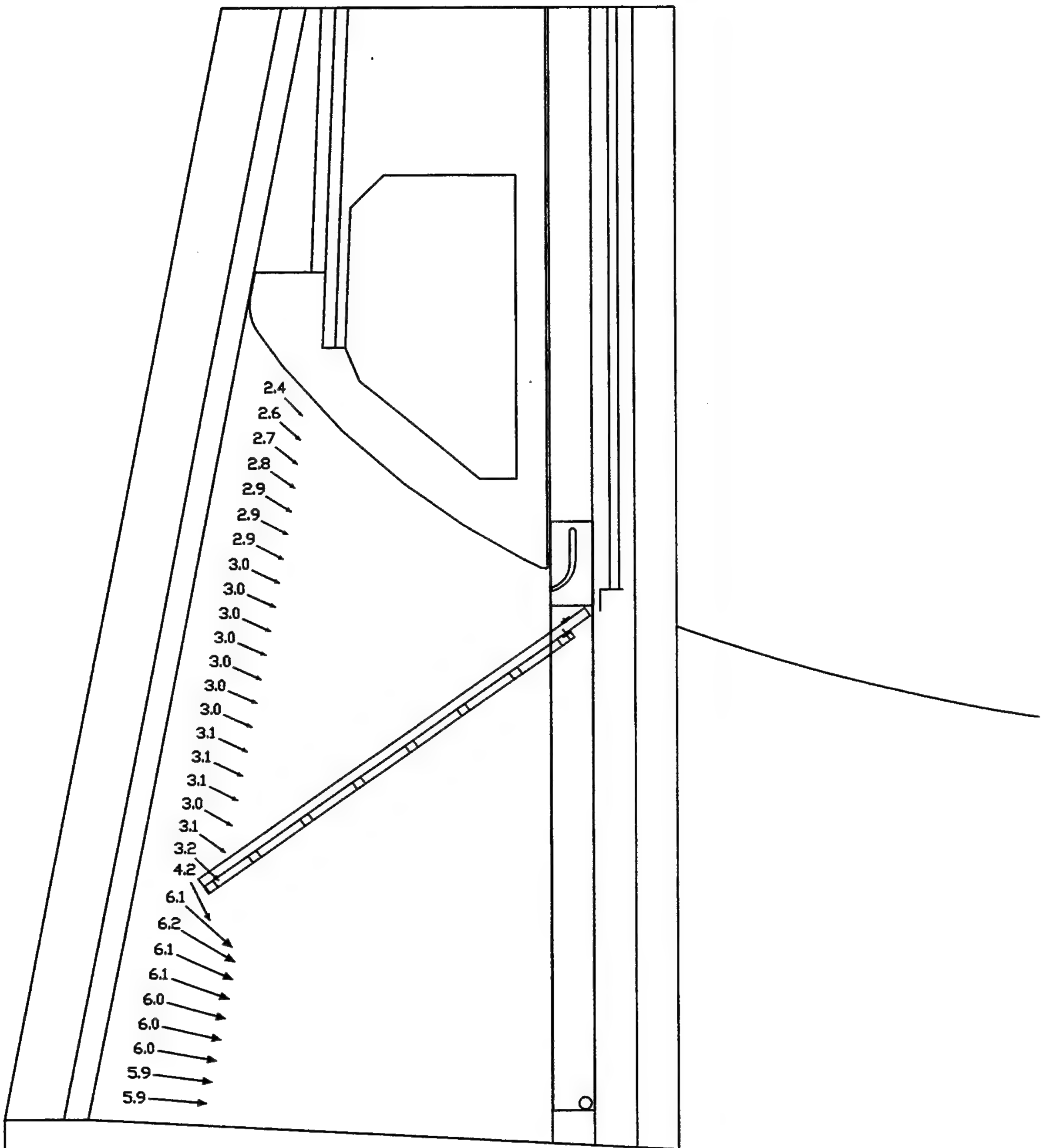

SCALE, PROTOTYPE FT
0
5
10
FLOW IN GATE SLOT = 547 CFS
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 45
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 2 IN PLACE
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST45.DWG

PLATE 37

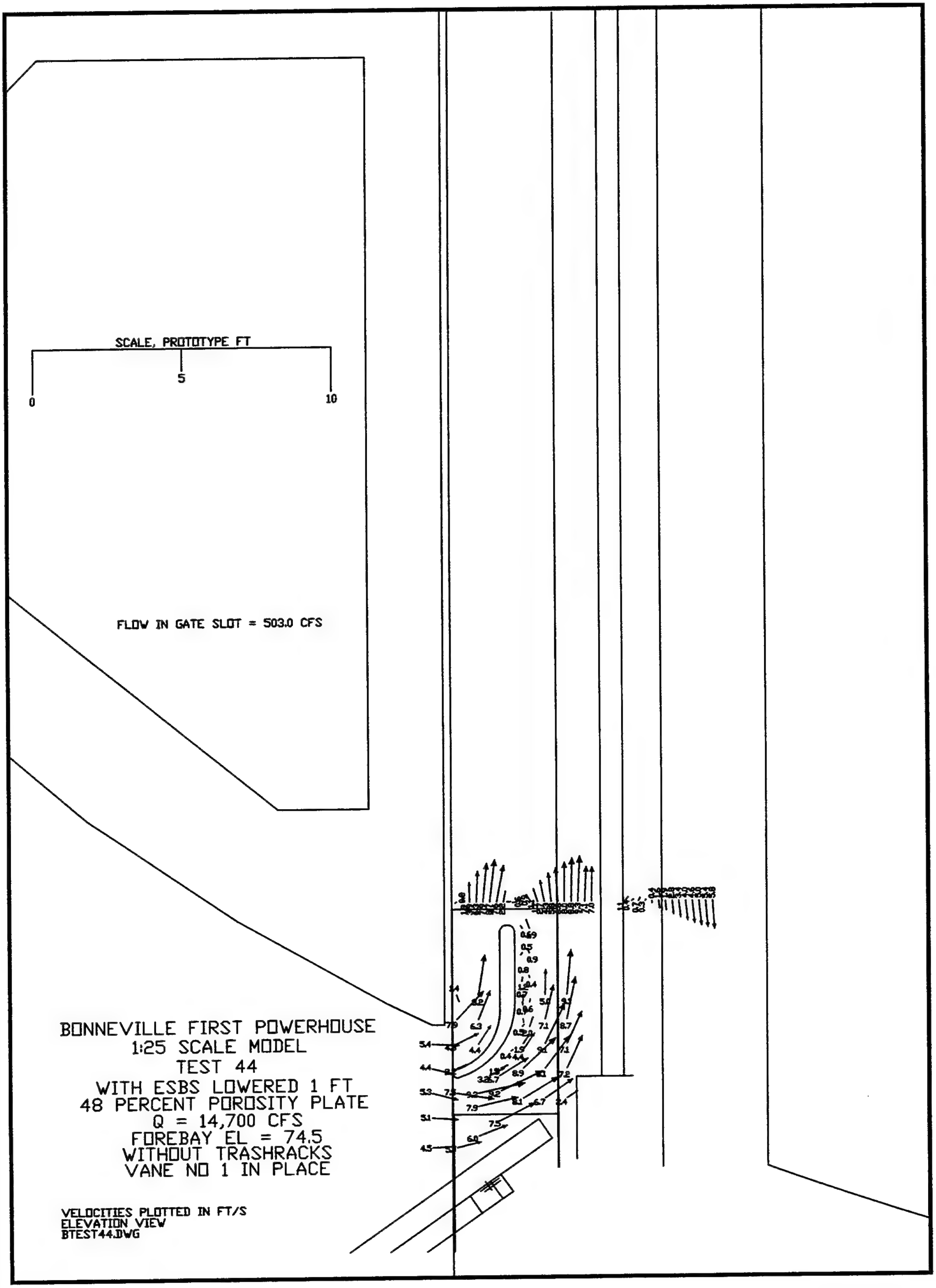


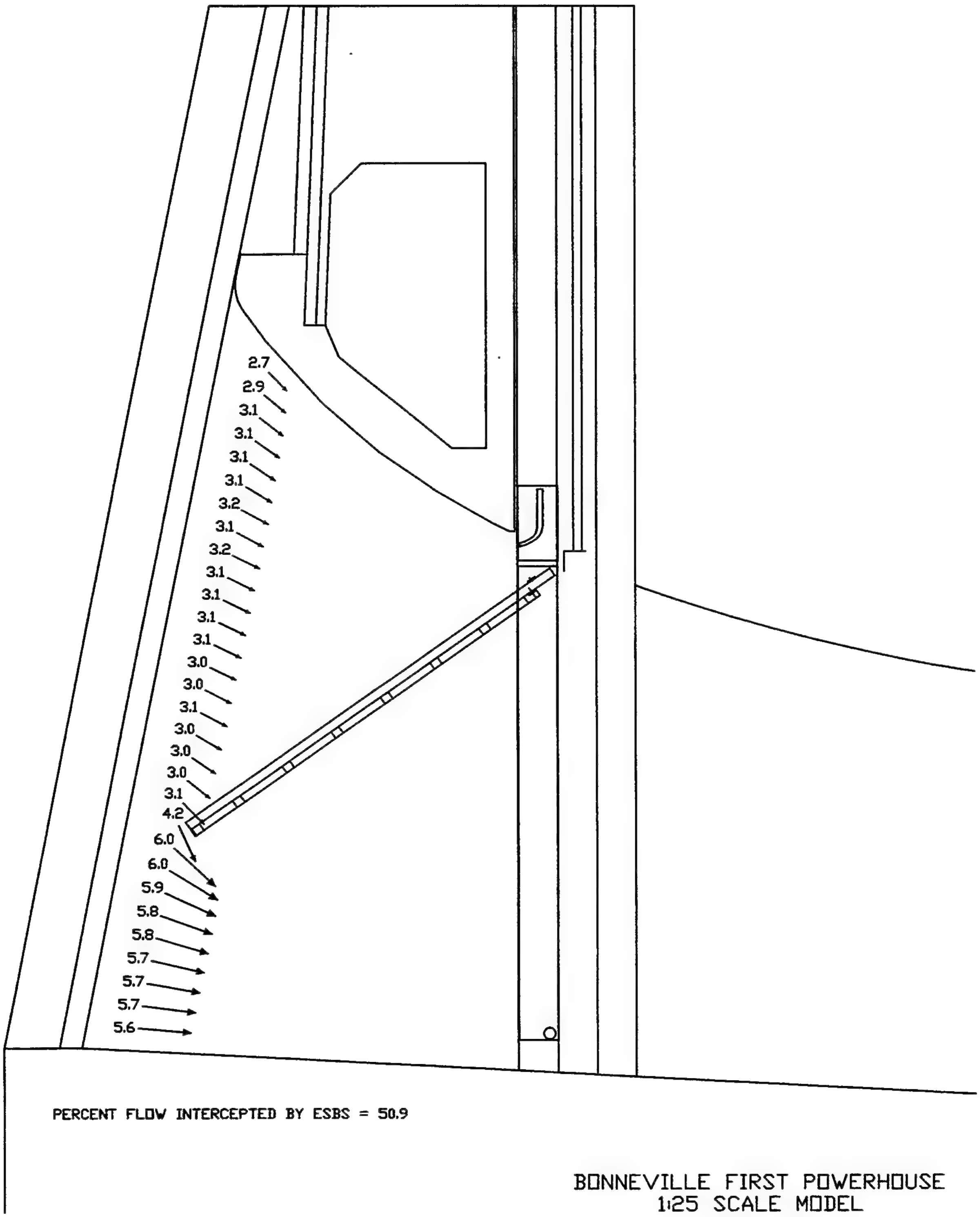
PERCENT FLOW INTERCEPTED BY ESBS = 49.2

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 44
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 1 IN PLACE

SCALE, PROTOTYPE FT
0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST44.DWG


SCALE, PROTOTYPE FT
0
5
10
FLOW IN GATE SLOT = 503.0 CFS
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 44
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 1 IN PLACE
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST44.DWG



PERCENT FLOW INTERCEPTED BY ESBS = 50.9

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 43
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 2 RAISED 0.5 FT

SCALE, PROTOTYPE FT
0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST43.DWG

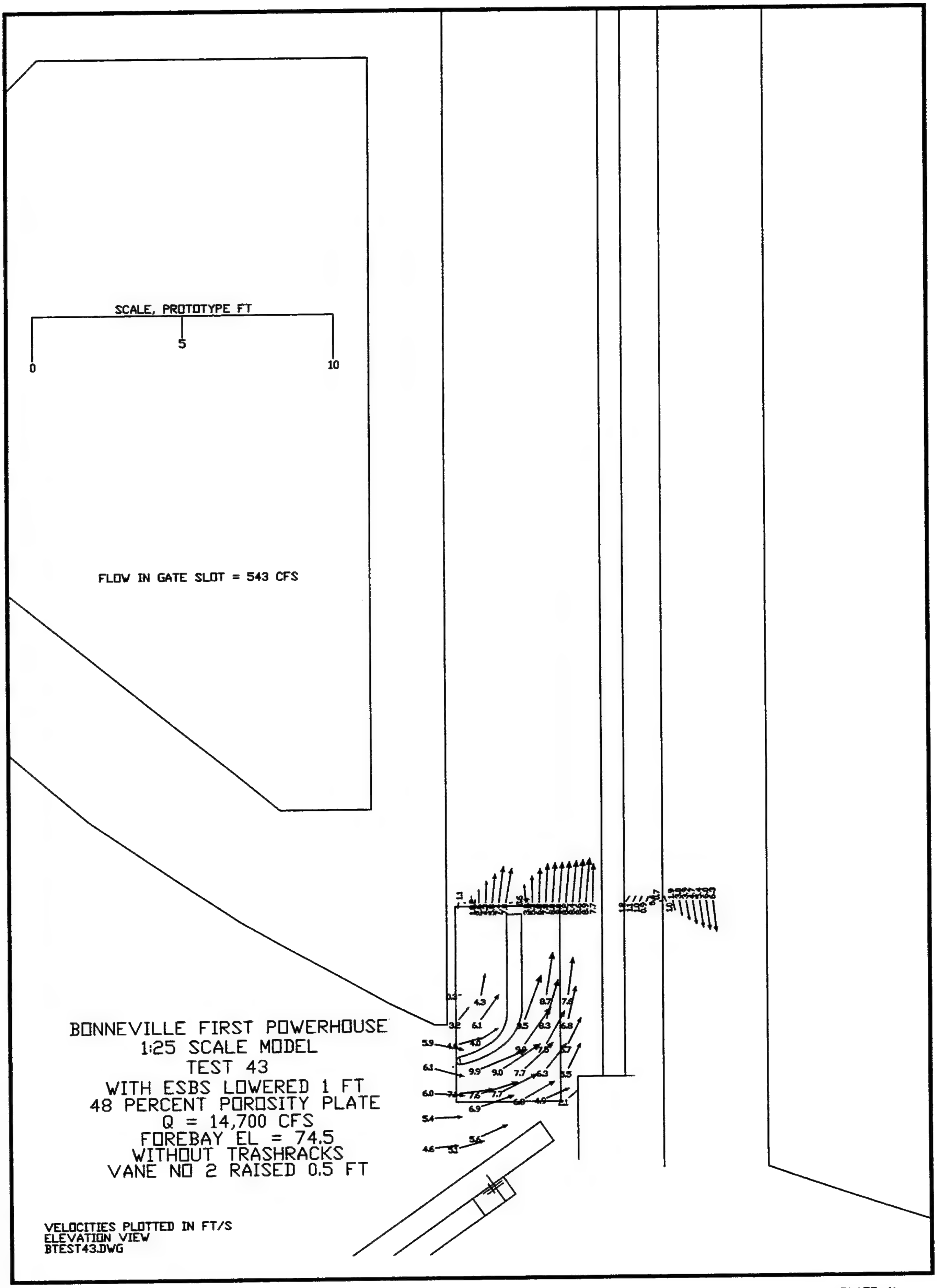
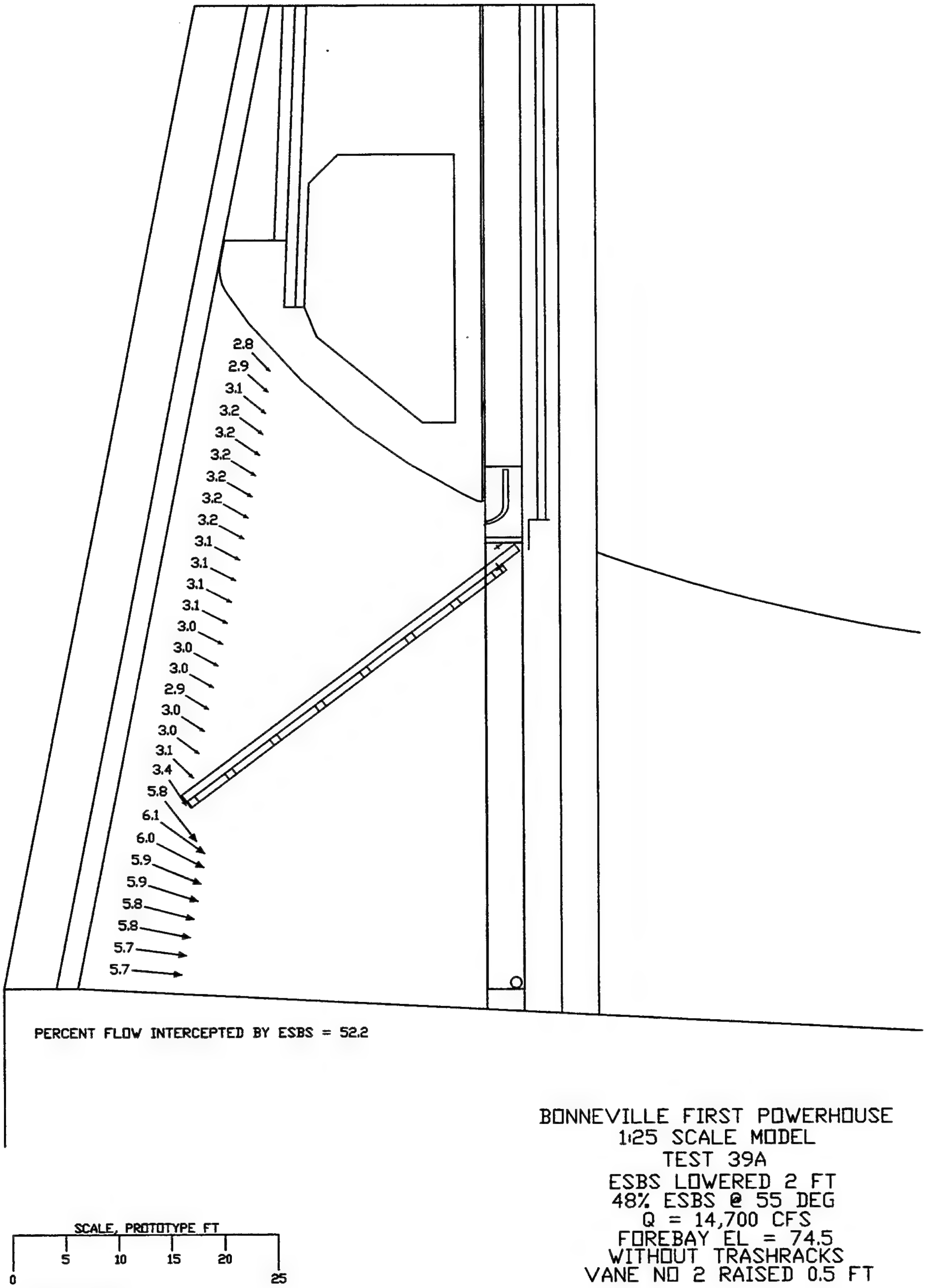

SCALE, PROTOTYPE FT
0
5
10
FLOW IN GATE SLOT = 543 CFS
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 43
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 2 RAISED 0.5 FT
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST43.DWG

PLATE 41



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TST39A.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 39A
ESBS LOWERED 2 FT
48% ESBS @ 55 DEG
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 2 RAISED 0.5 FT

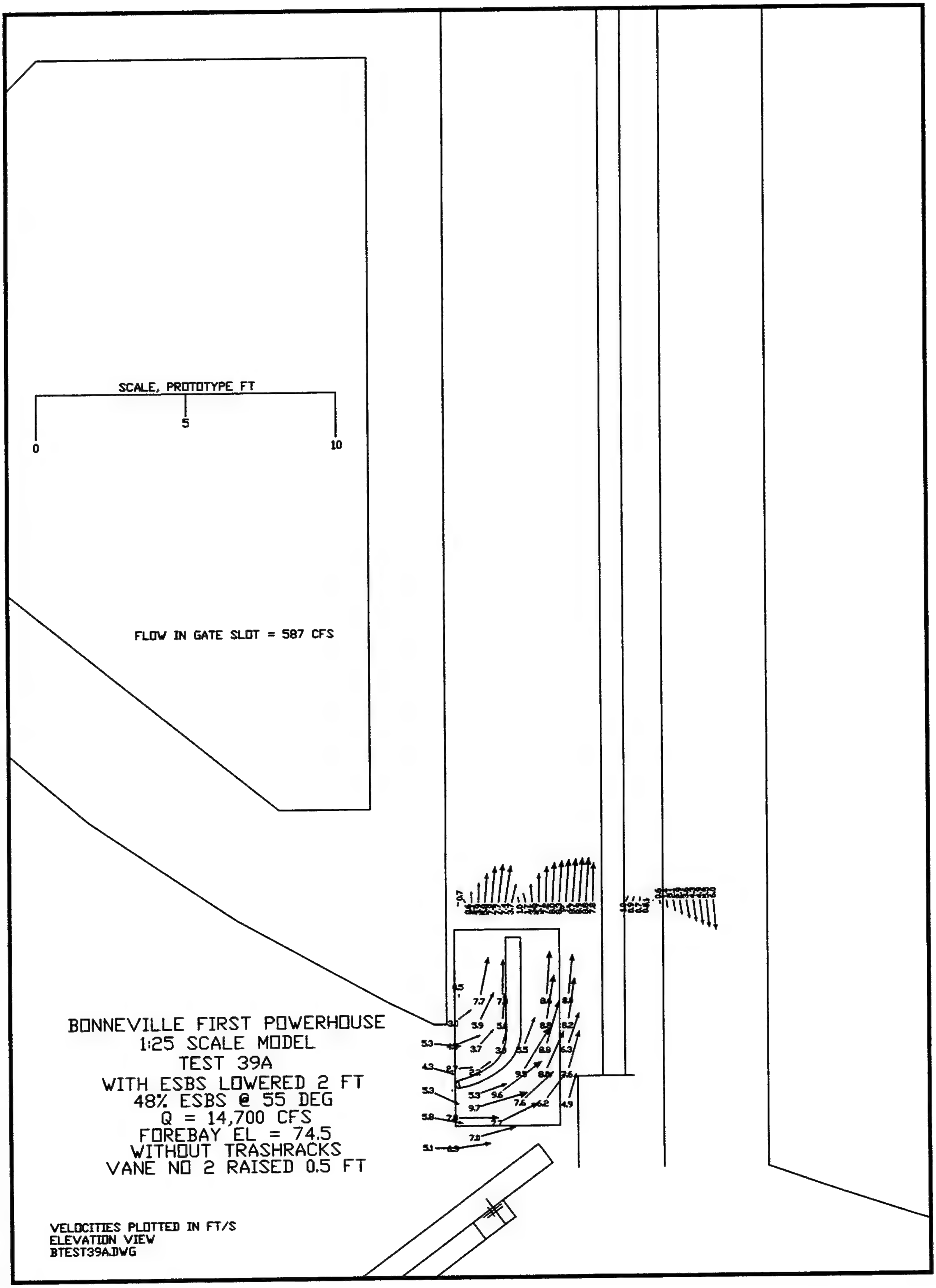
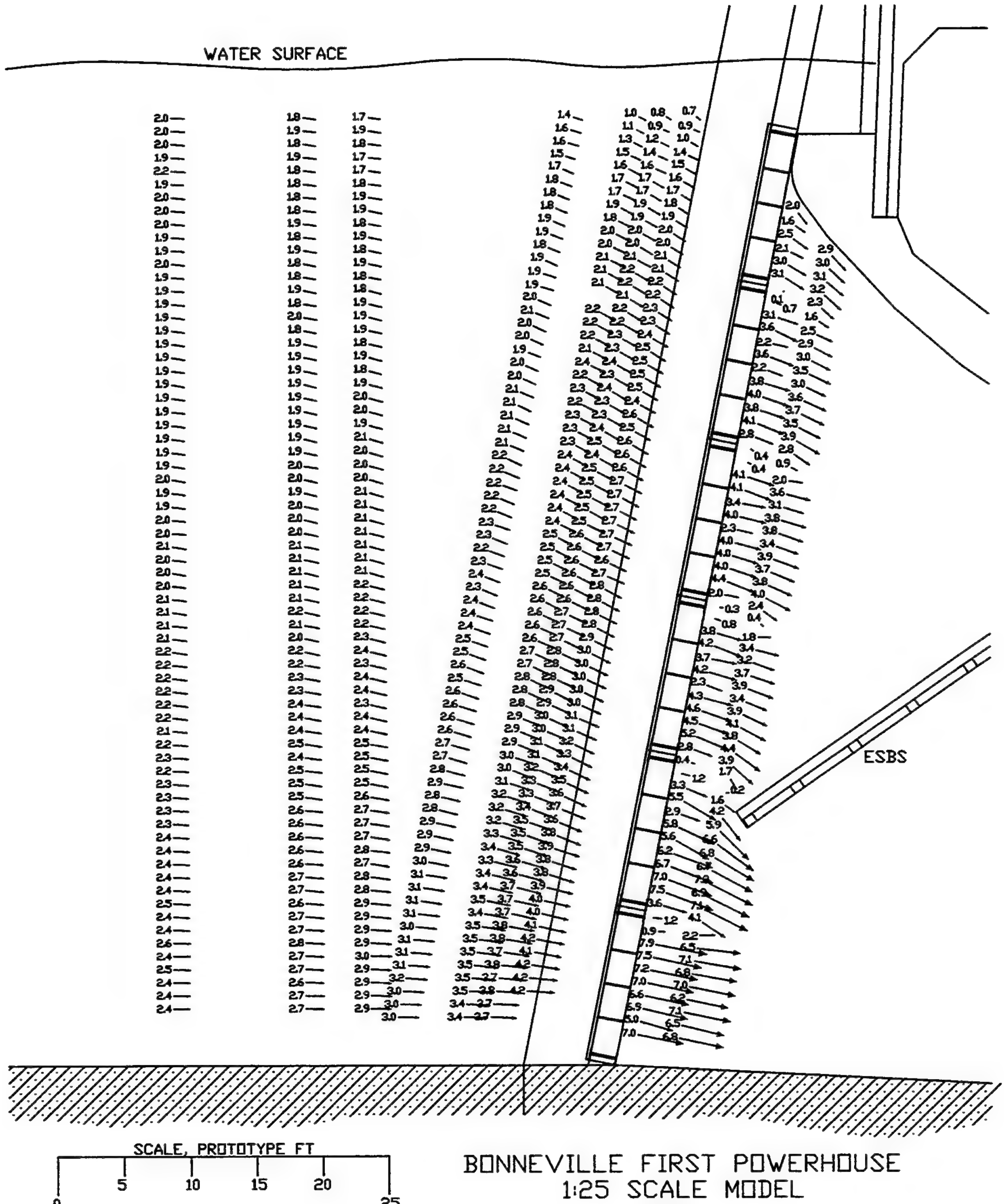
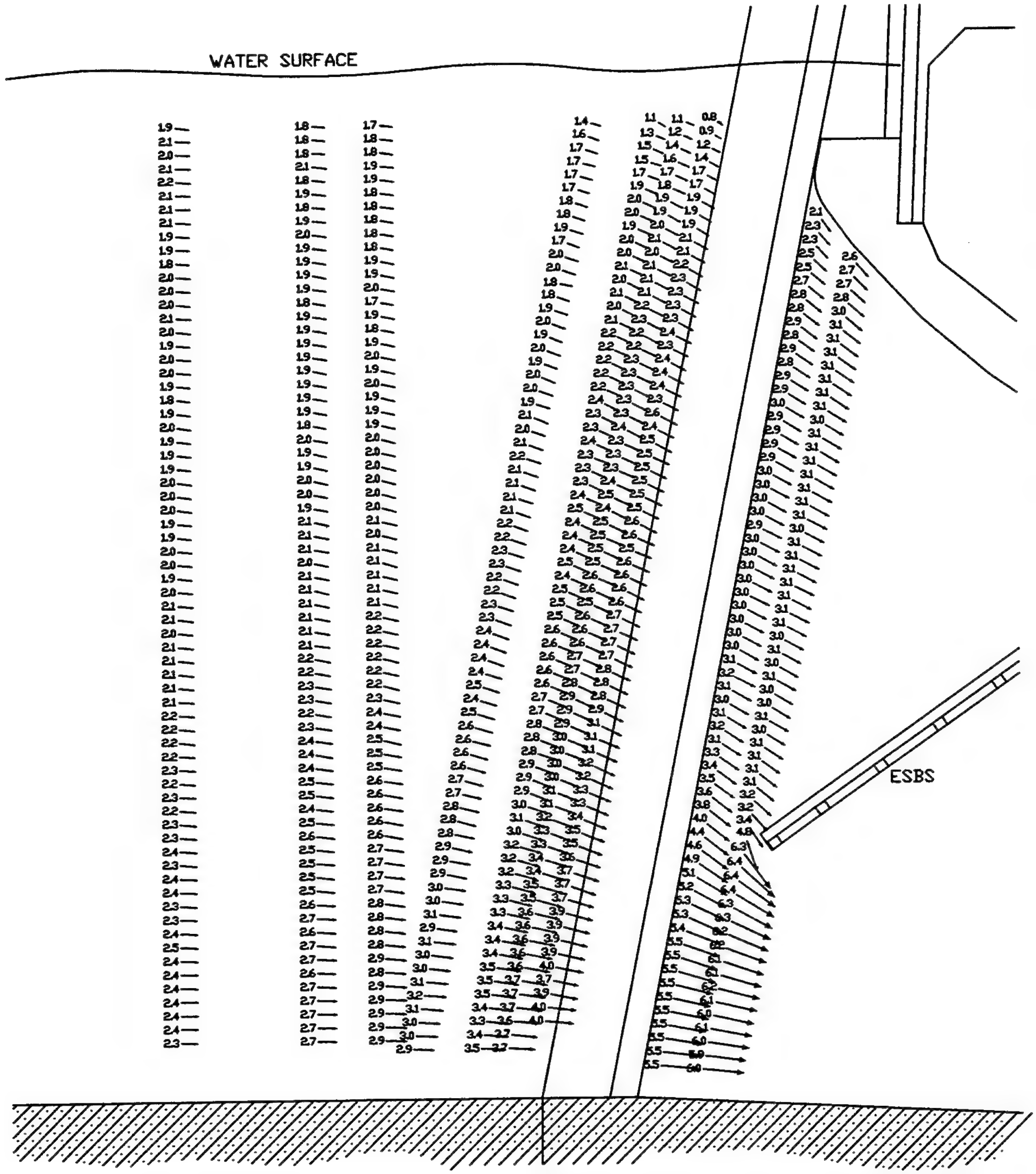

SCALE, PROTOTYPE FT
0
5
10
FLOW IN GATE SLOT = 587 CFS
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 39A
WITH ESBS LOWERED 2 FT
48% ESBS @ 55 DEG
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
VANE NO 2 RAISED 0.5 FT
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST39A.DWG

PLATE 43



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST71.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 71
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
ORIGINAL TRASHRACKS IN PLACE

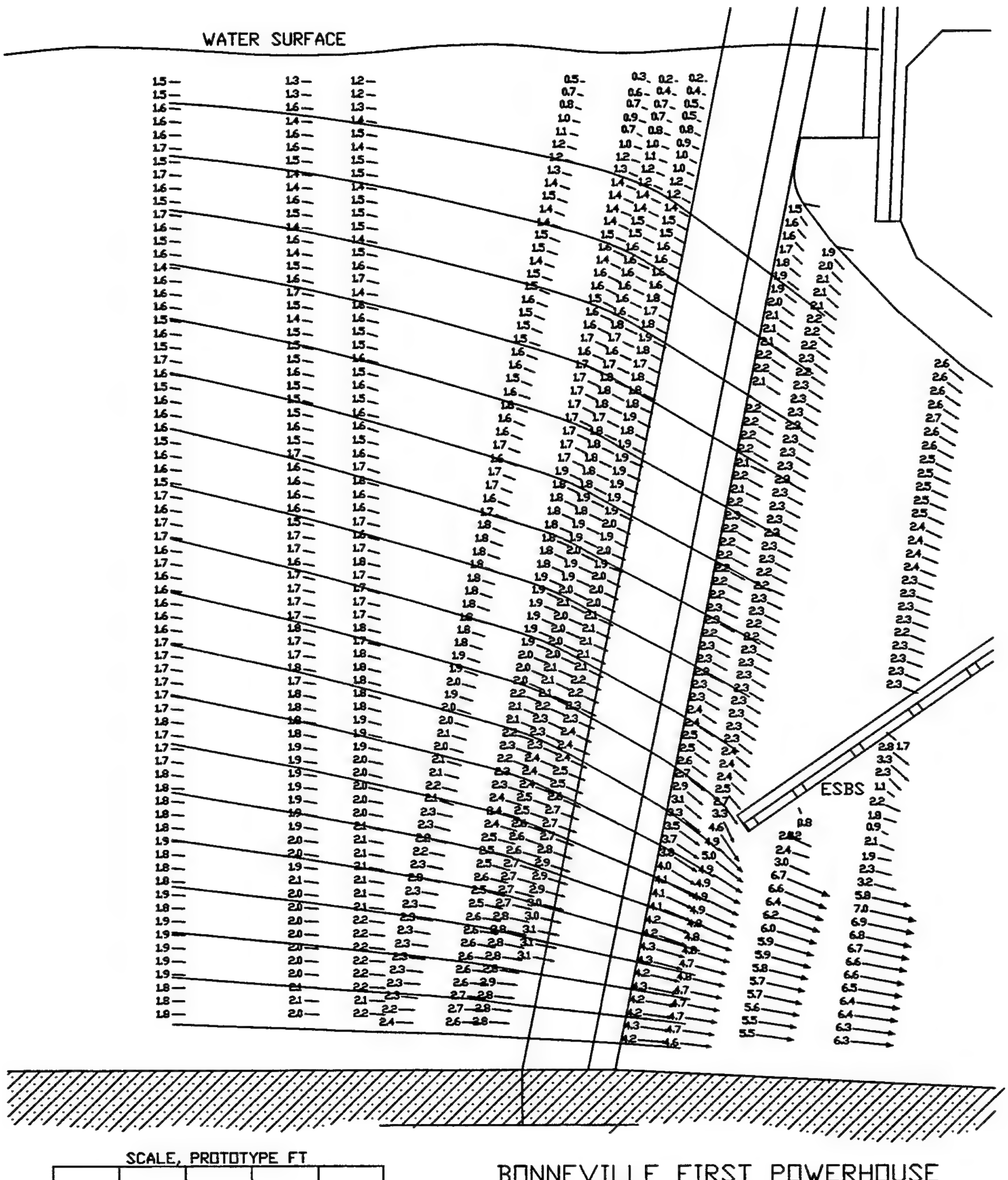


SCALE, PROTOTYPE FT

0 5 10 15 20 25

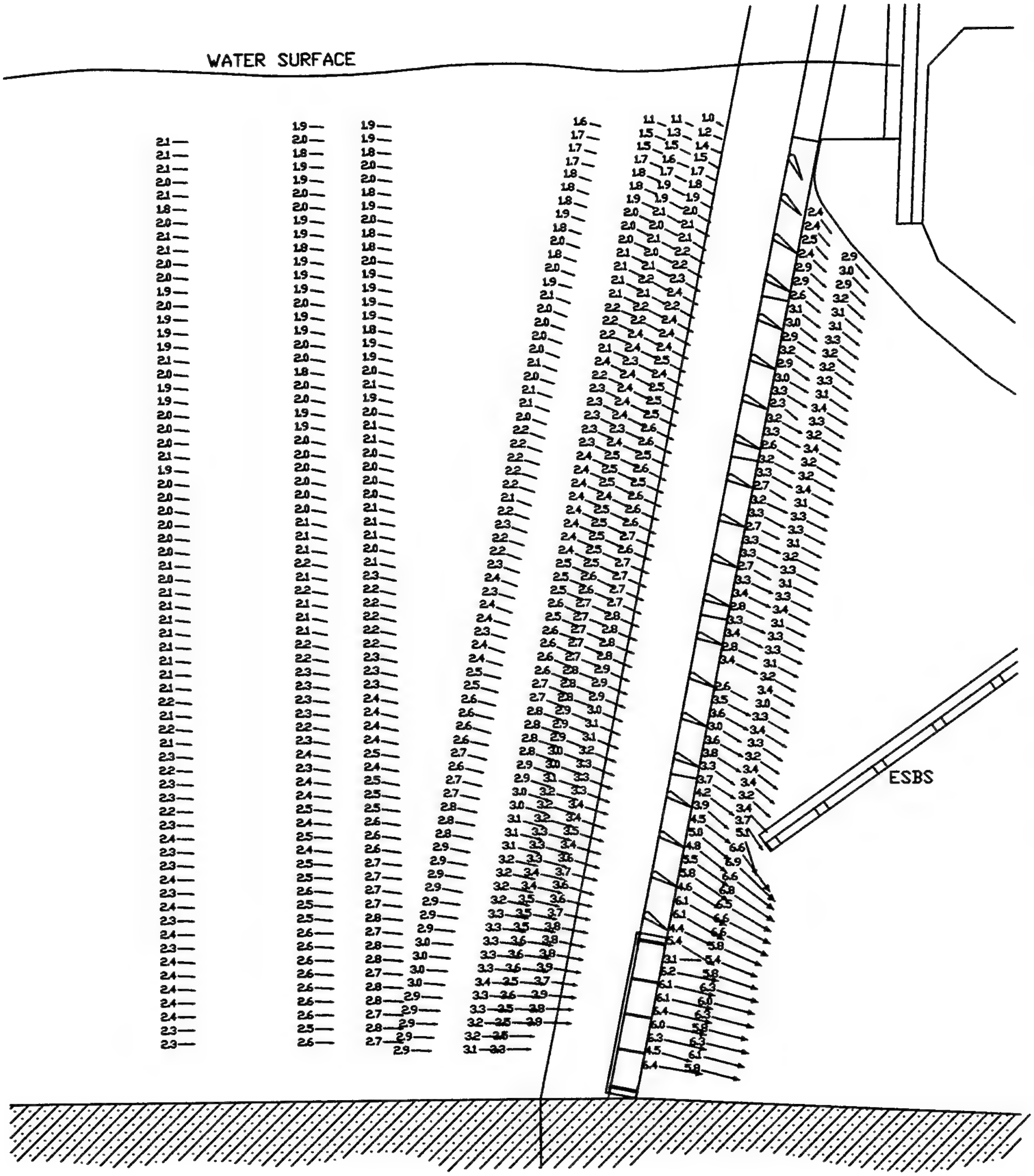
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST70.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 70
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST86.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 86
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS

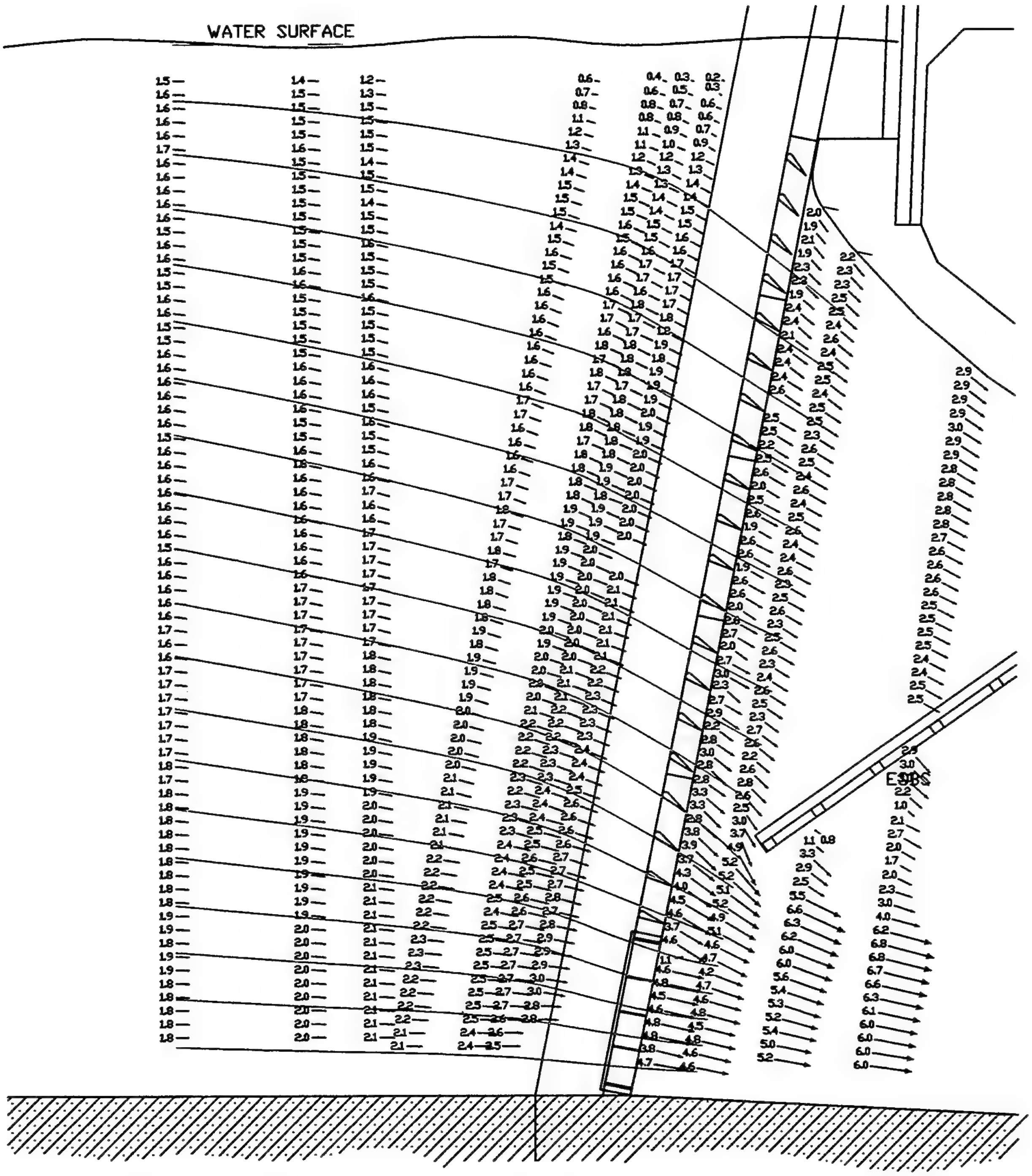


SCALE, PROTOTYPE FT

0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST69.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 69
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH STREAMLINED TRASHRACKS CONFIG 1

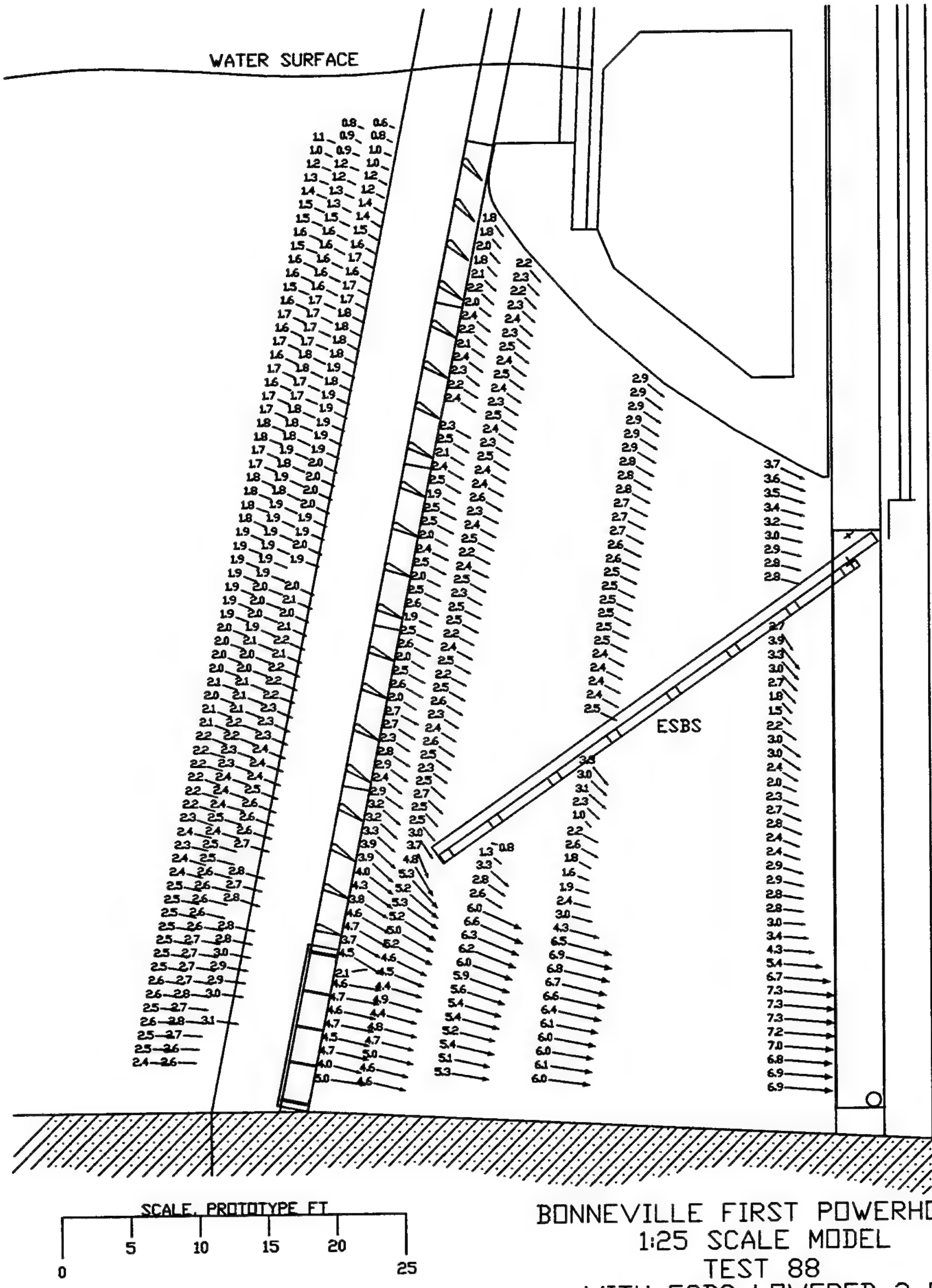


SCALE, PROTOTYPE FT

0 5 10 15 20 25

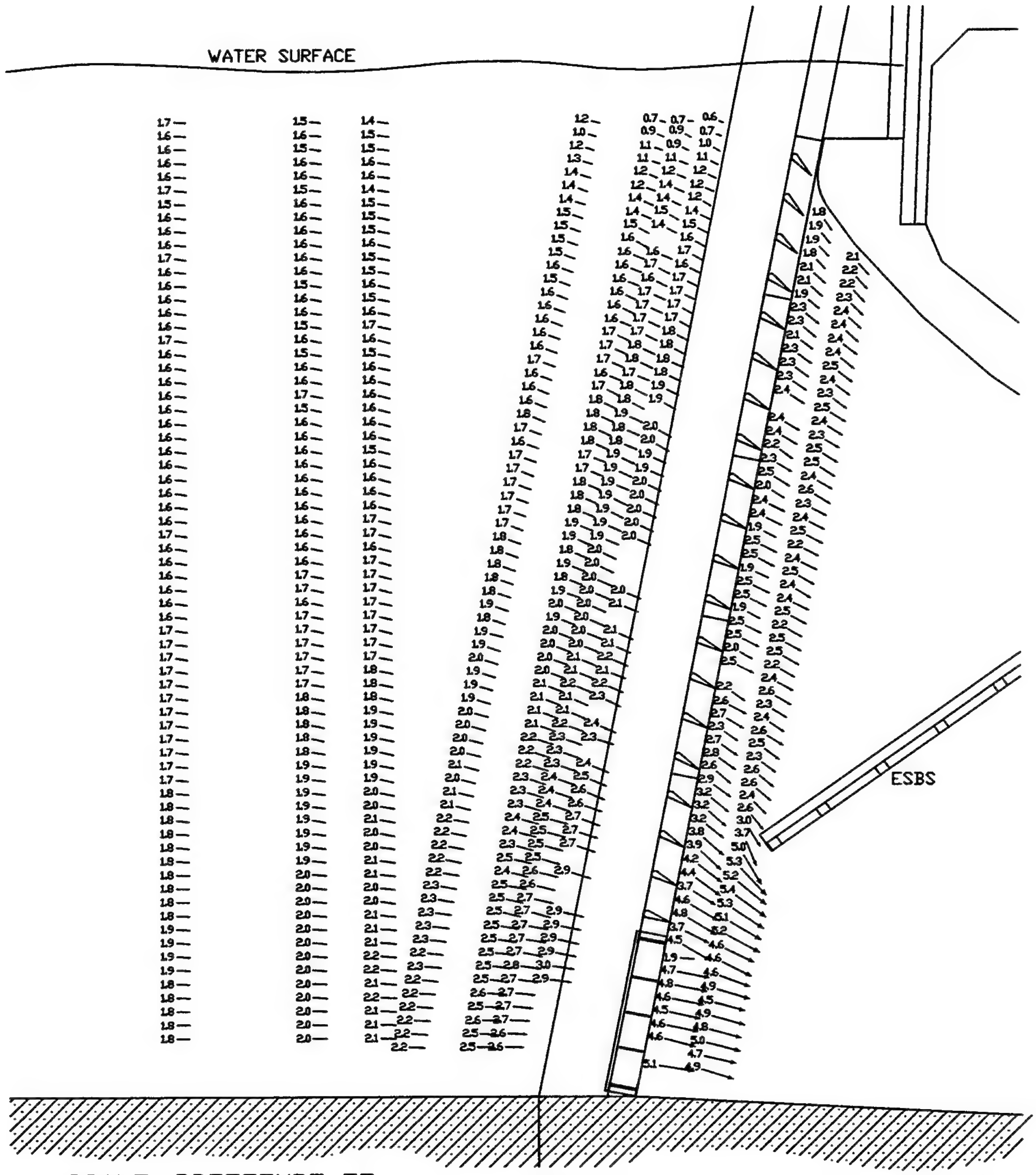
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST87.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 87
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
STREAMLINED TRASHRACK CONFIG 10



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST88.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 88
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
STREAMLINED TRASHRACK CONFIG 11

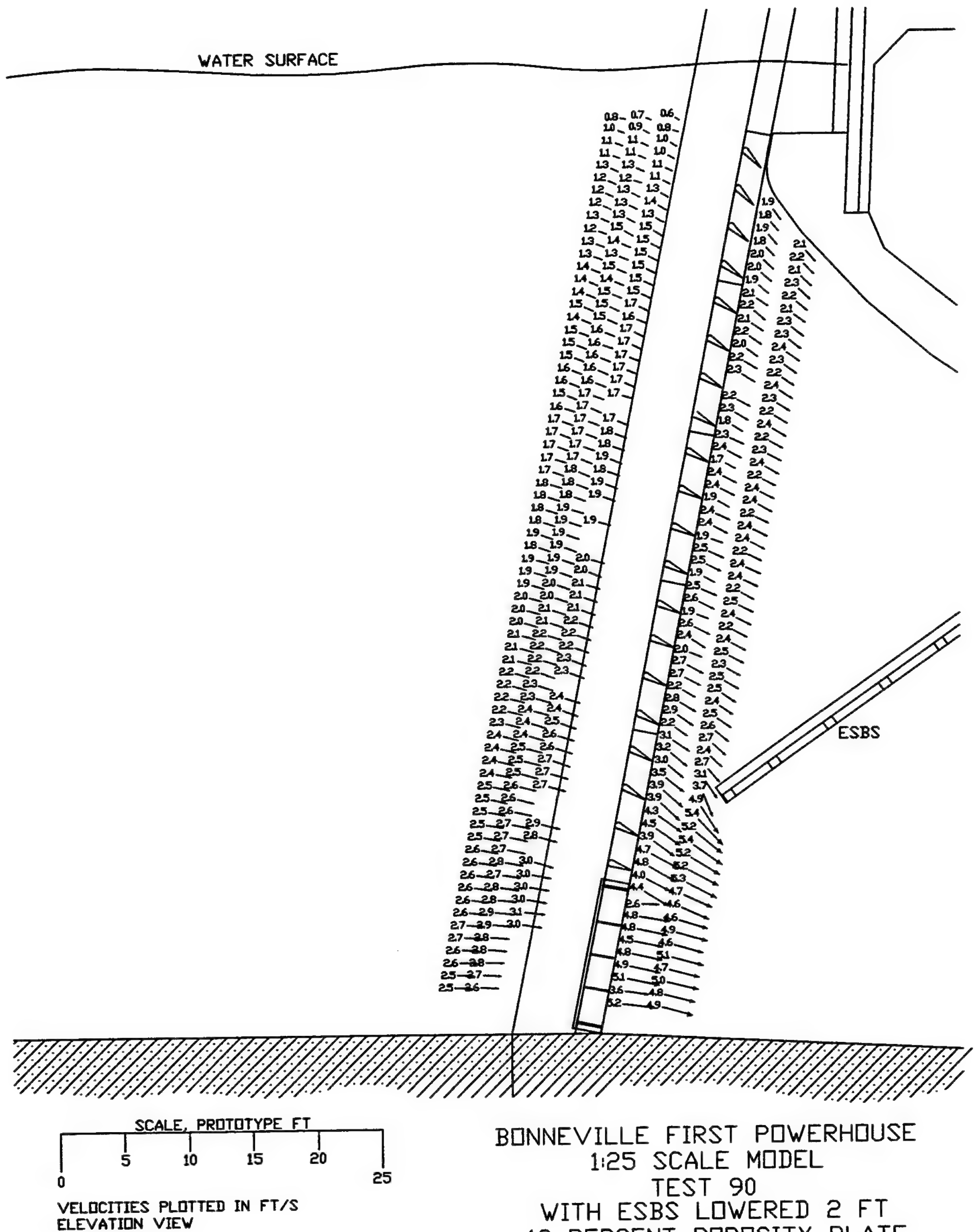


SCALE, PROTOTYPE FT

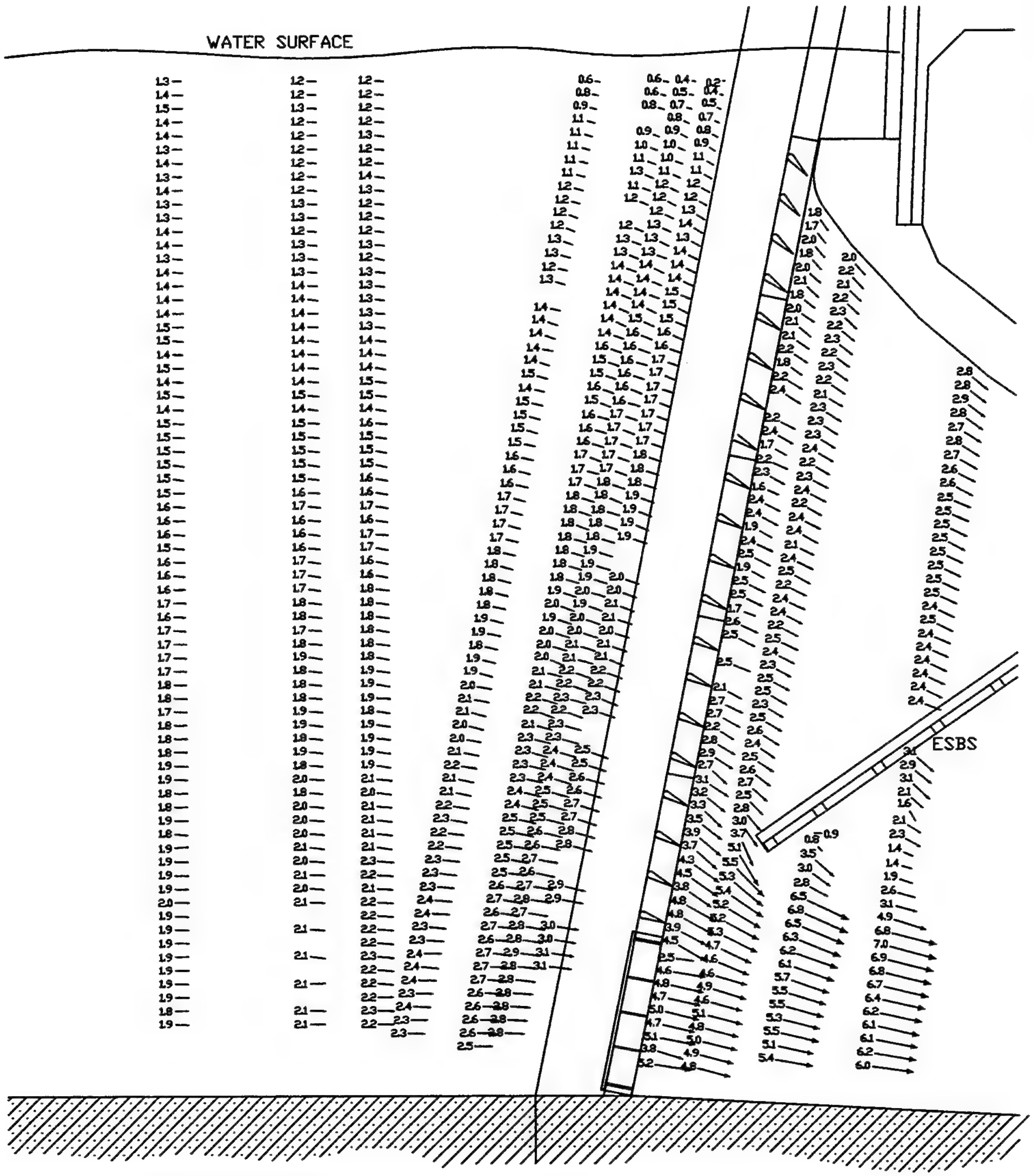
0 5 10 15 20 25

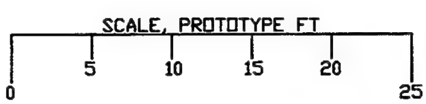
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST89.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 89
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
STREAMLINED TRASHRACK CONFIG 12



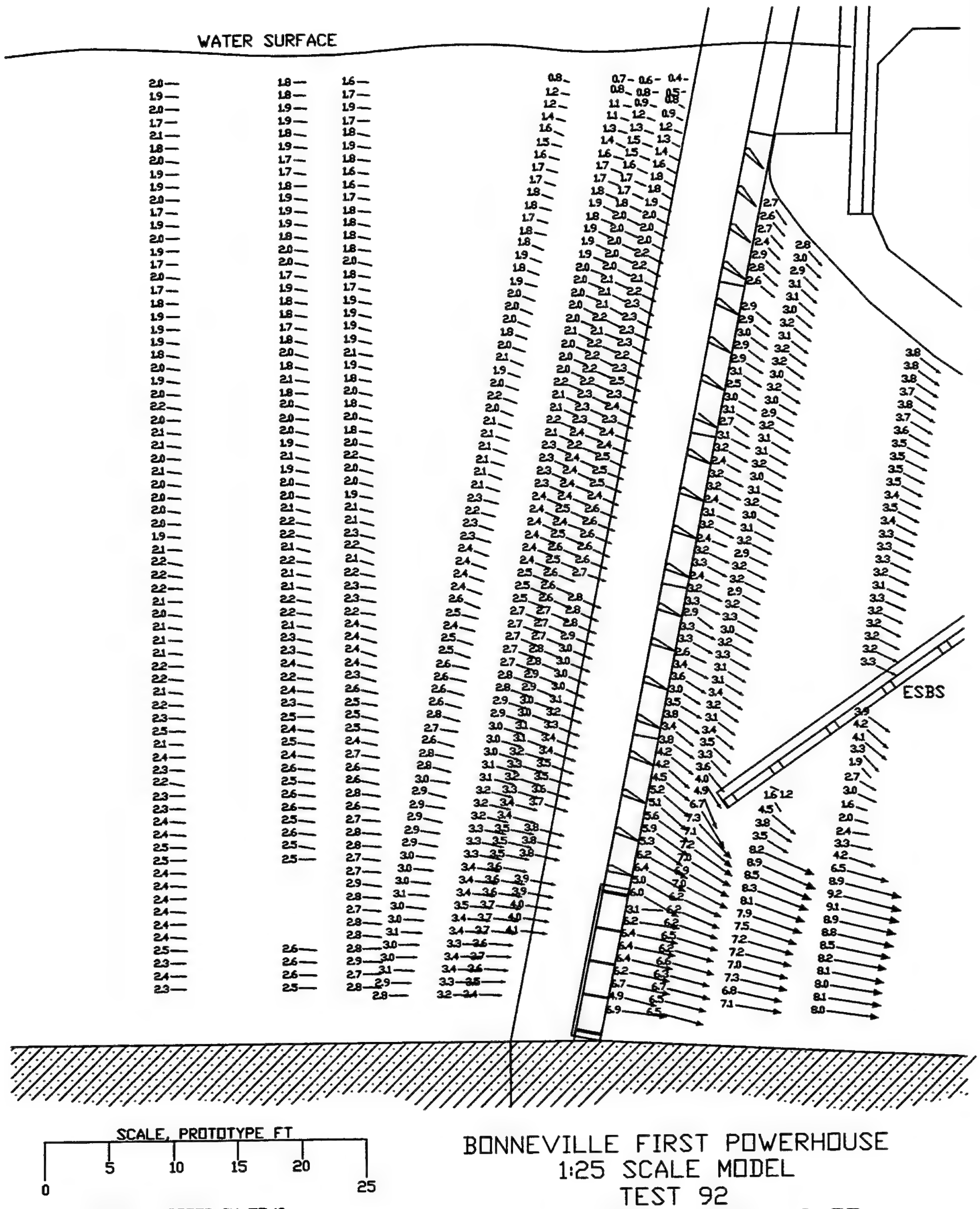
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 90
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
STREAMLINED TRASHRACK CONFIG 12





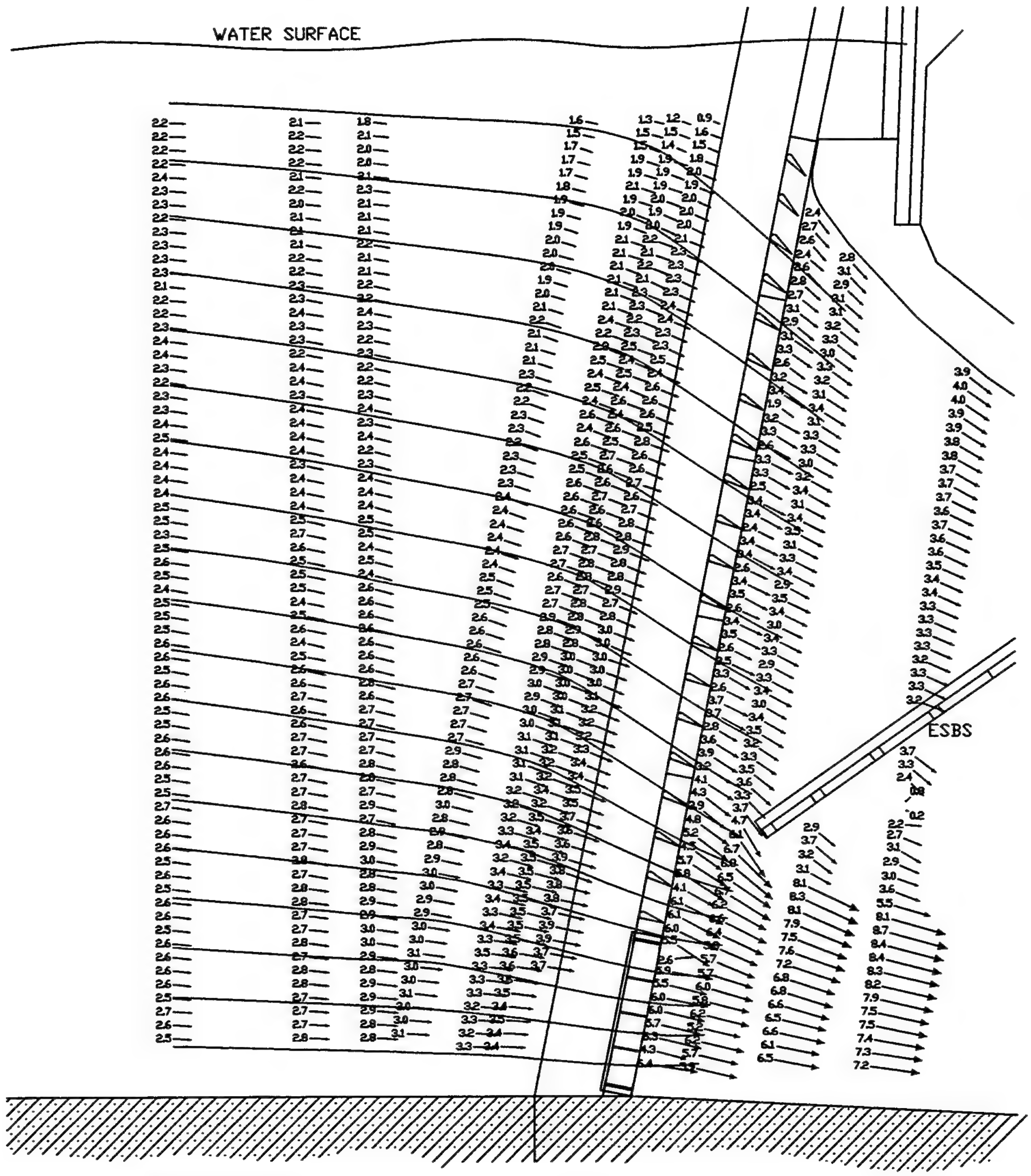
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST91.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 91
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
STREAMLINED TRASHRACK CONFIG 13



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST92.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 92
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
STREAMLINED TRASHRACK CONFIG 13

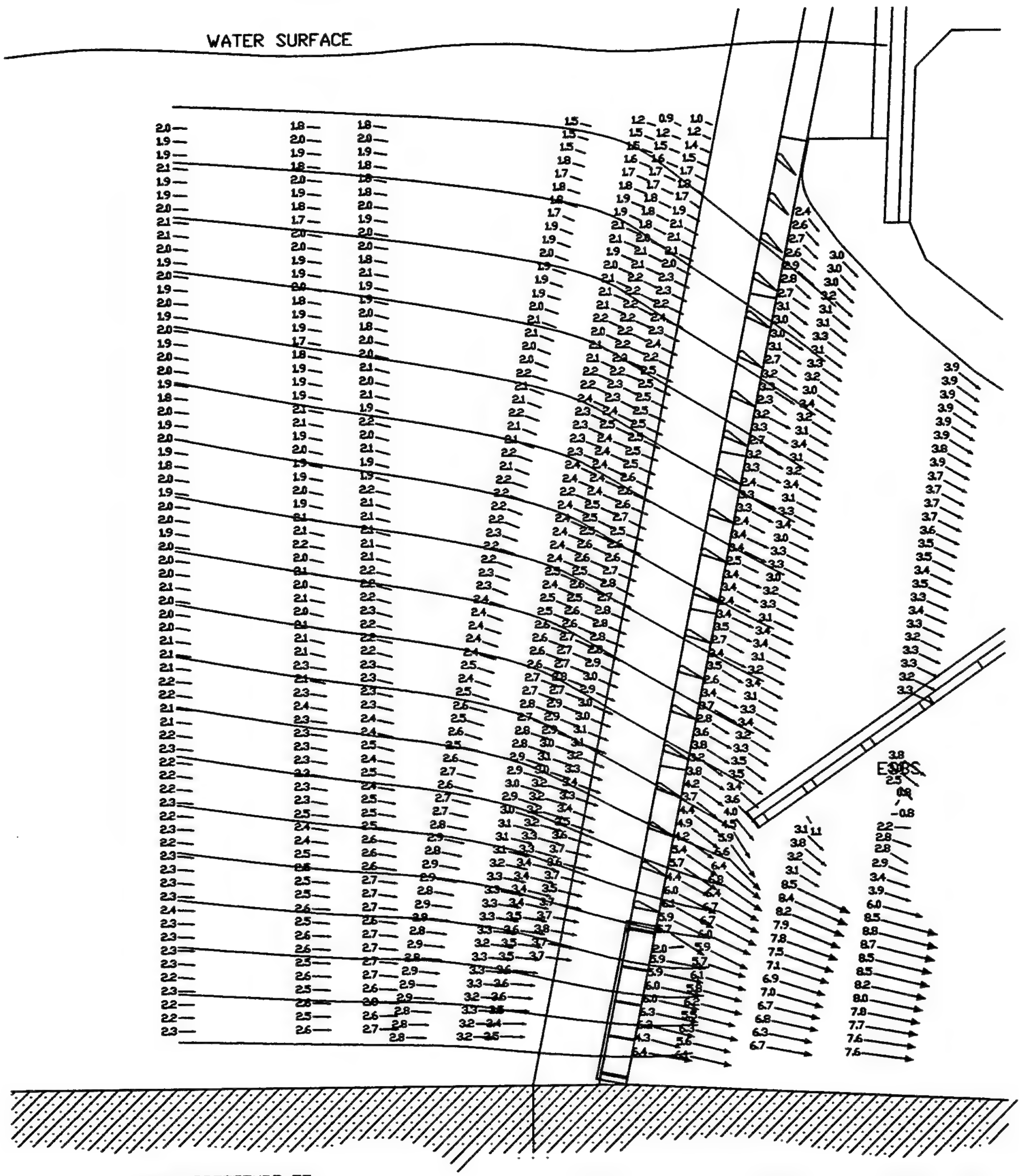


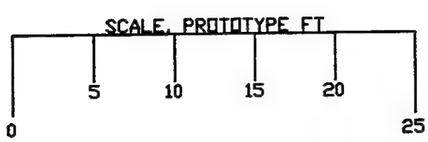
SCALE, PROTOTYPE FT

0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST96F.DWG

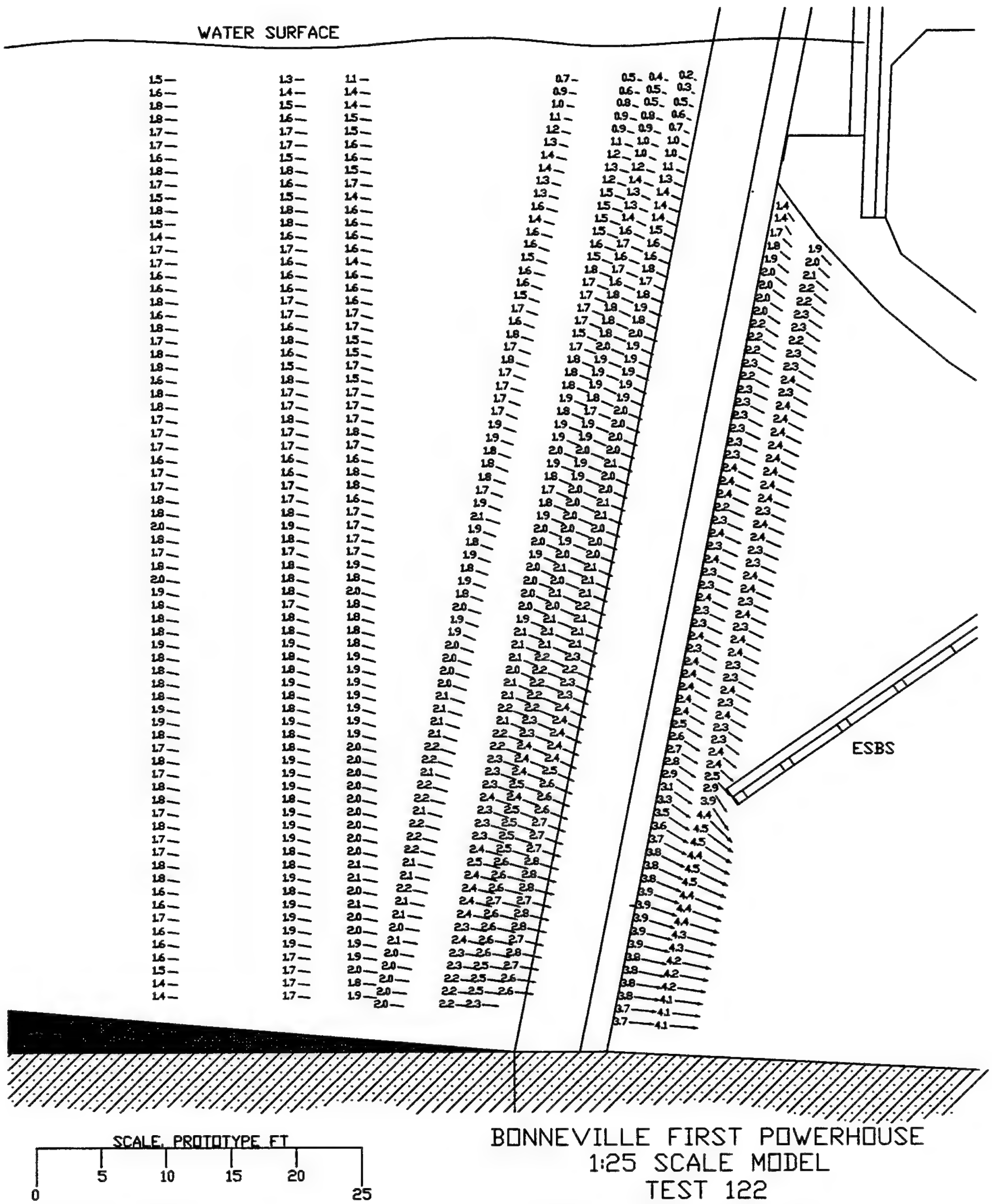
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 96
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
STREAMLINED CONFIG 13





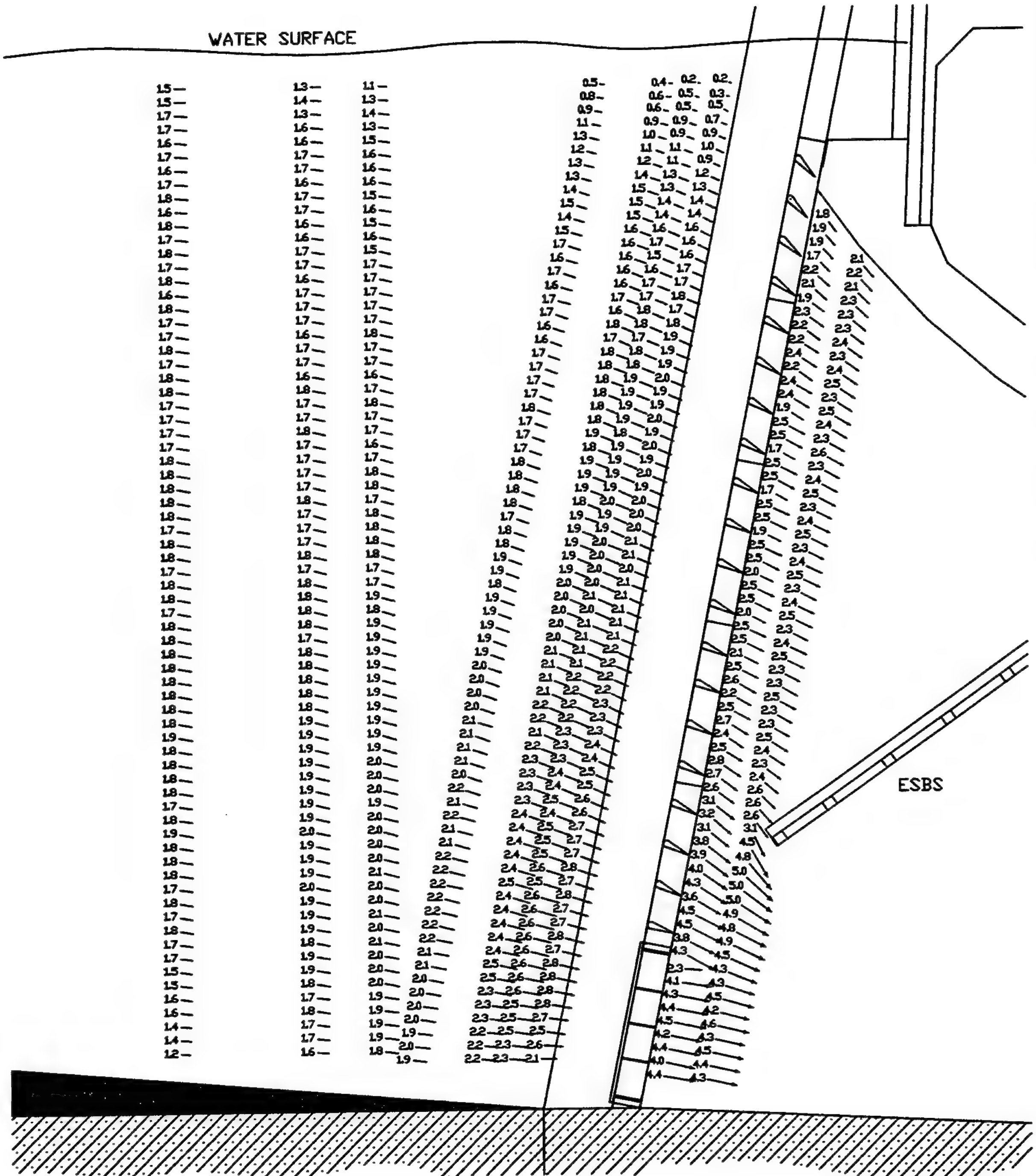
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST97F.DWG
PERCENT FLOW INTERCEPTED BY ESBS = 52.6

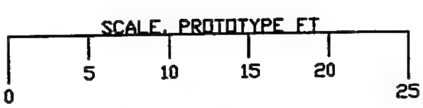
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 97
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
STREAMLINED CONFIG 14



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST122.DWG

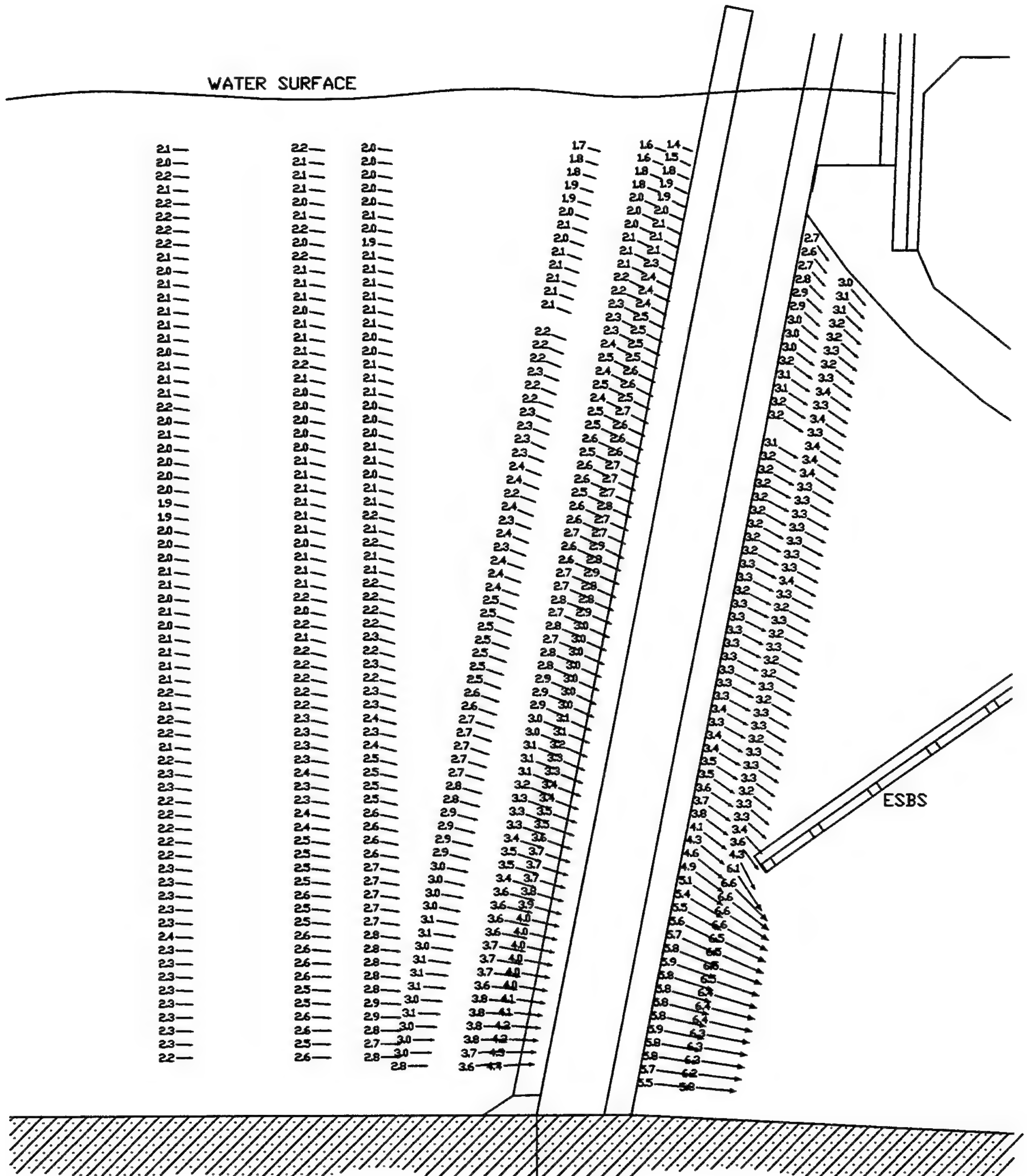
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 122
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
UNIT EIGHT TOPO IN PLACE
WITHOUT TRASHRACKS

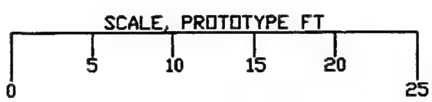




VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST123.DWG

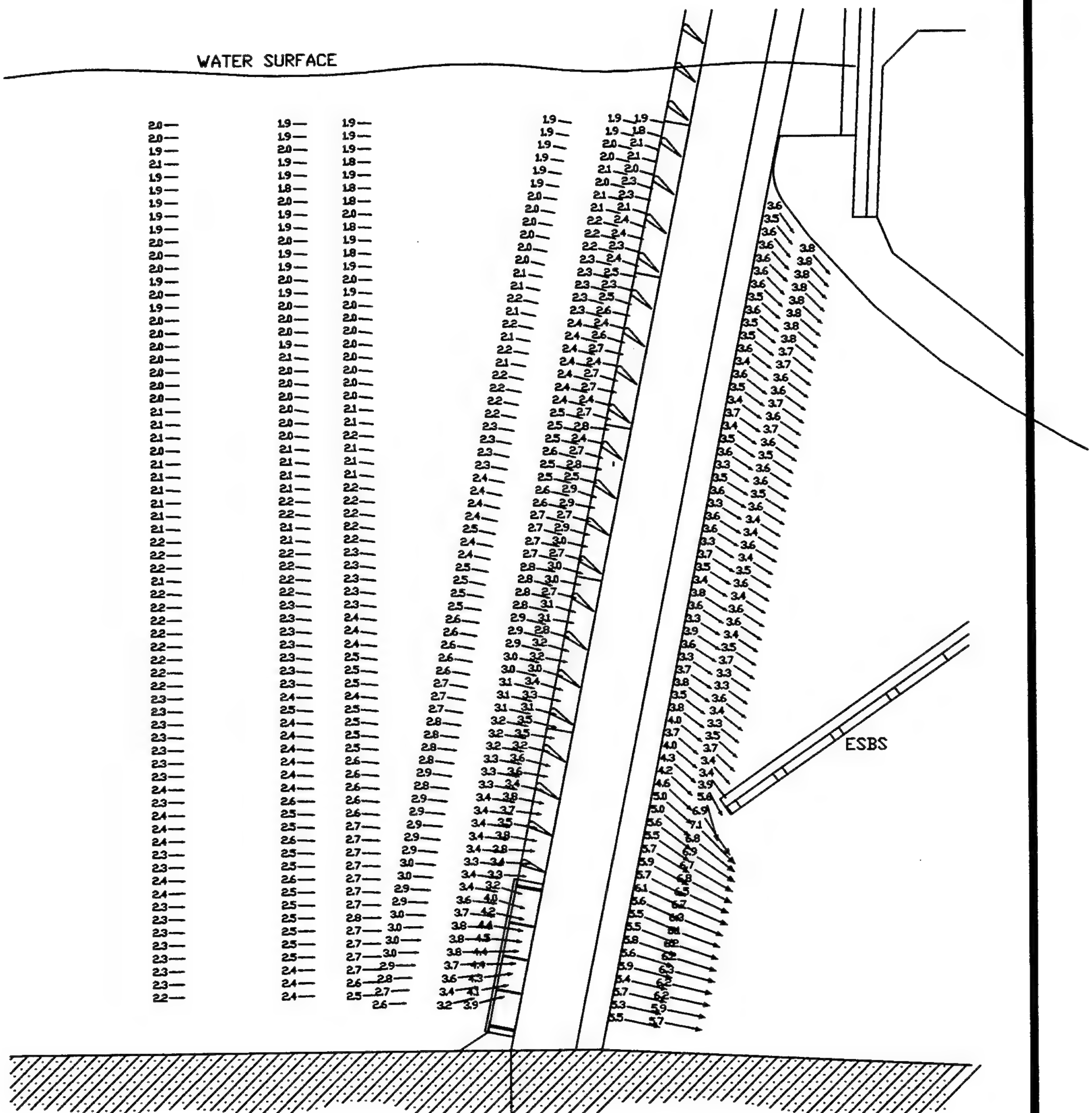
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 123
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
UNIT EIGHT TOPO IN PLACE
TRASHRACK CONFIGURATION #13

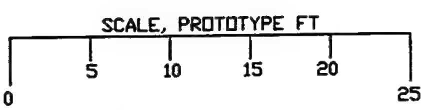




VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST75.DWG

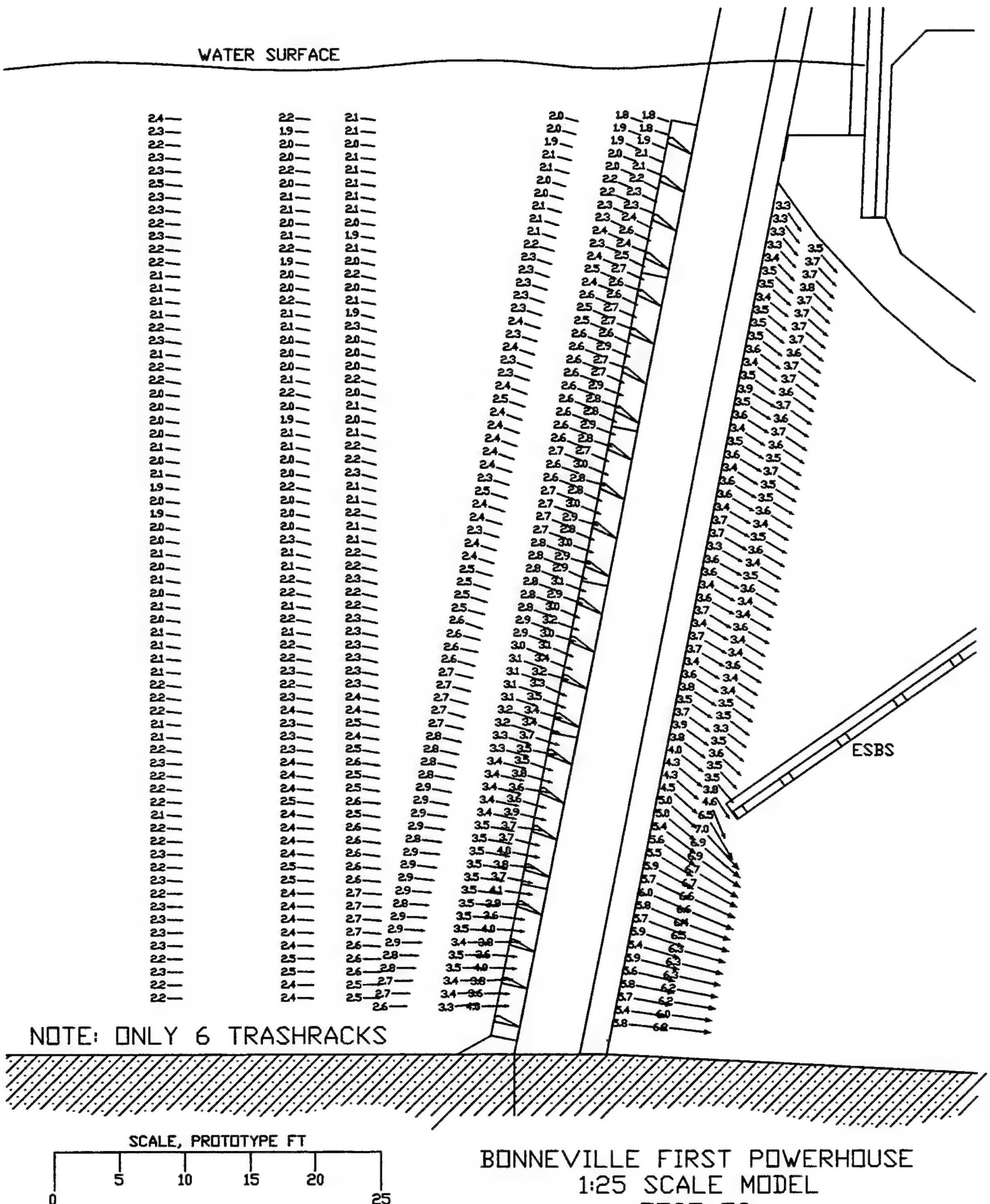
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 75
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
WITH PIER NOSE FRAME





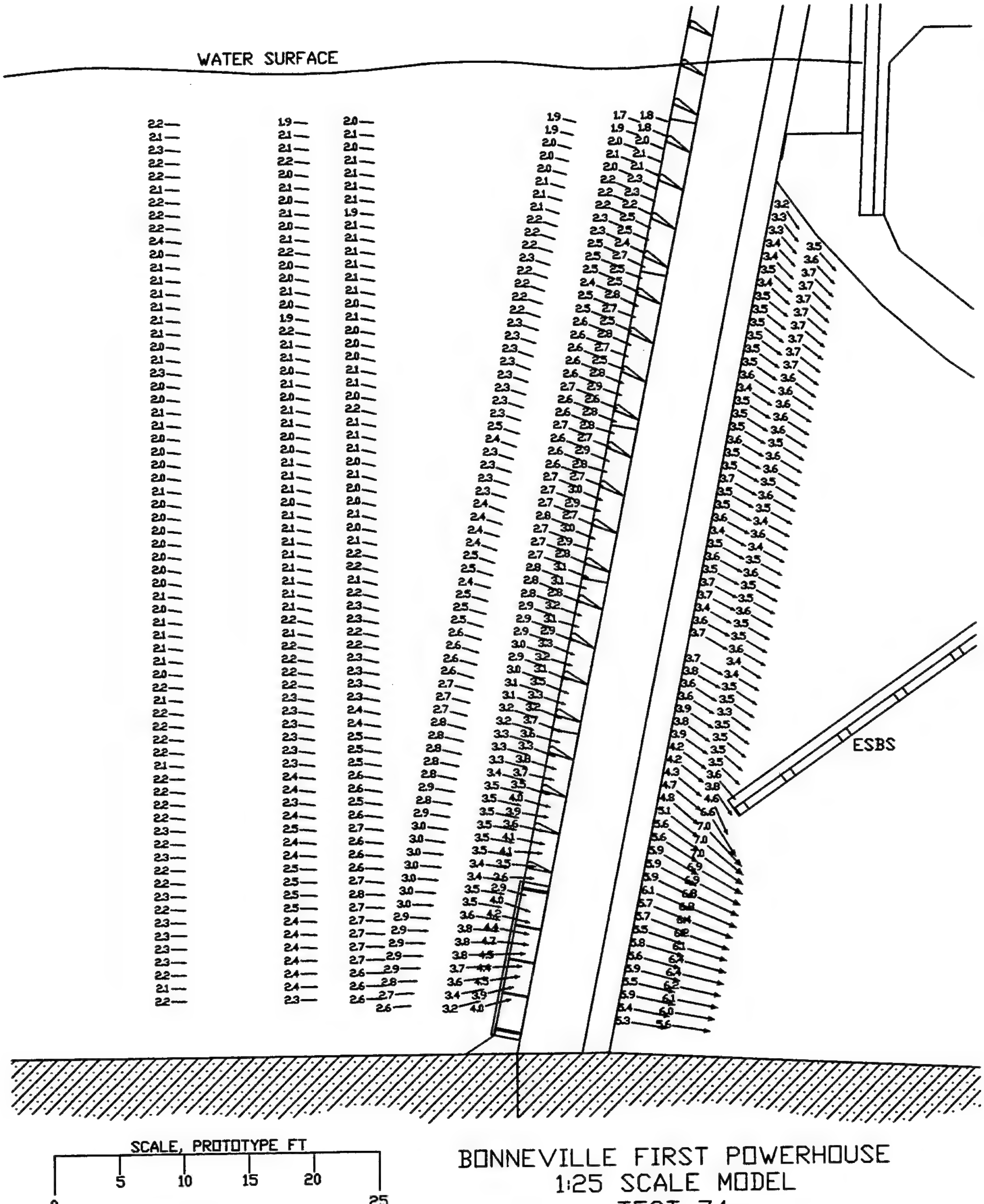
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST72.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 72
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH STREAMLINED TRASHRACKS CONFIG 2



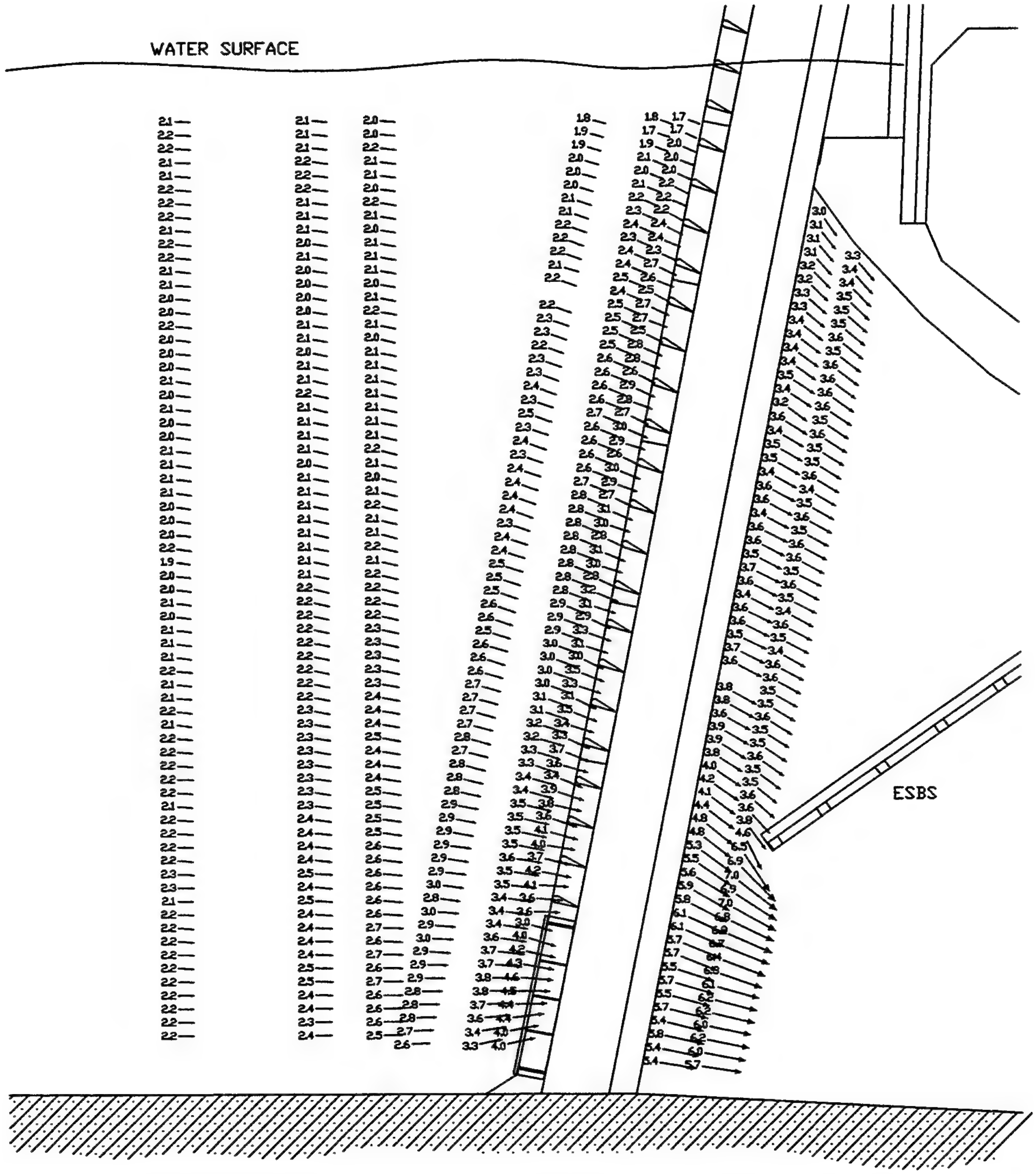
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST73.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 73
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH STREAMLINED TRASHRACKS CONFIG 3



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST74.DWG

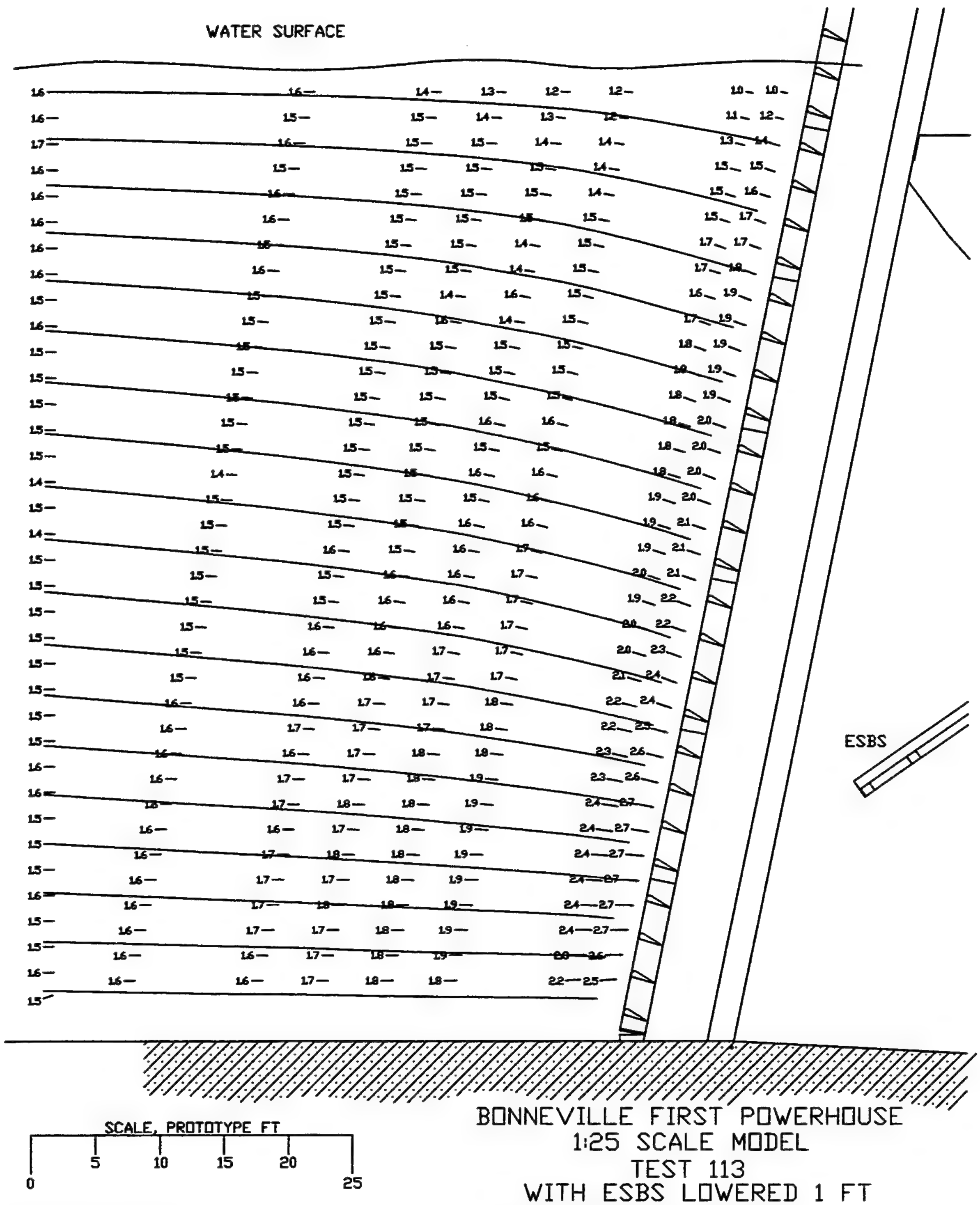
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 74
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH STREAMLINED TRASHRACKS CONFIG 3



SCALE, PROTOTYPE FT
0 5 10 15 20 25

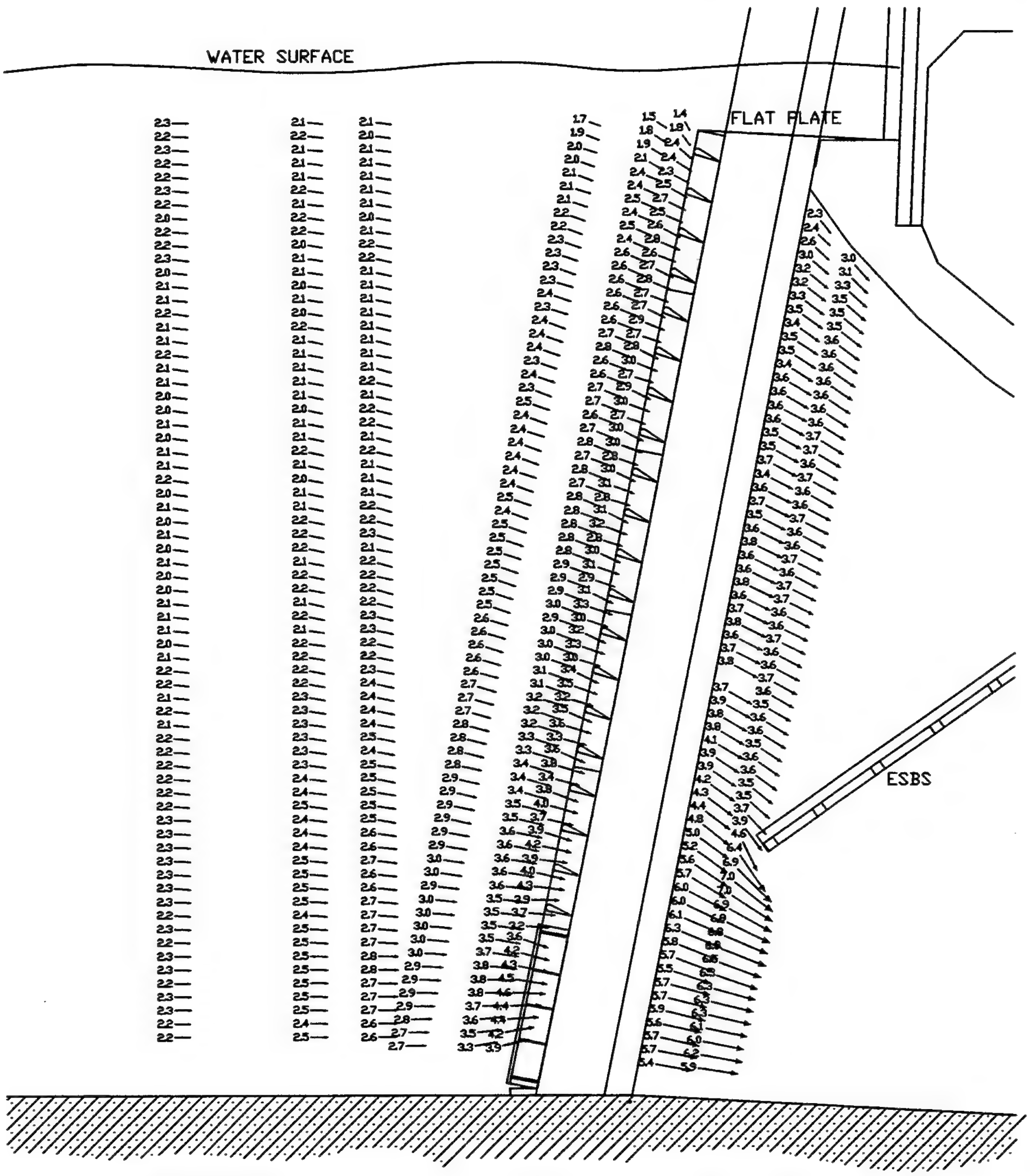
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST76.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 76
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH STREAMLINED TRASHRACKS CONFIG 5



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST113.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 113
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
TRASHRACK MEMBERS ANGLED @ 13.7 DEG
BAY C AVE VEL

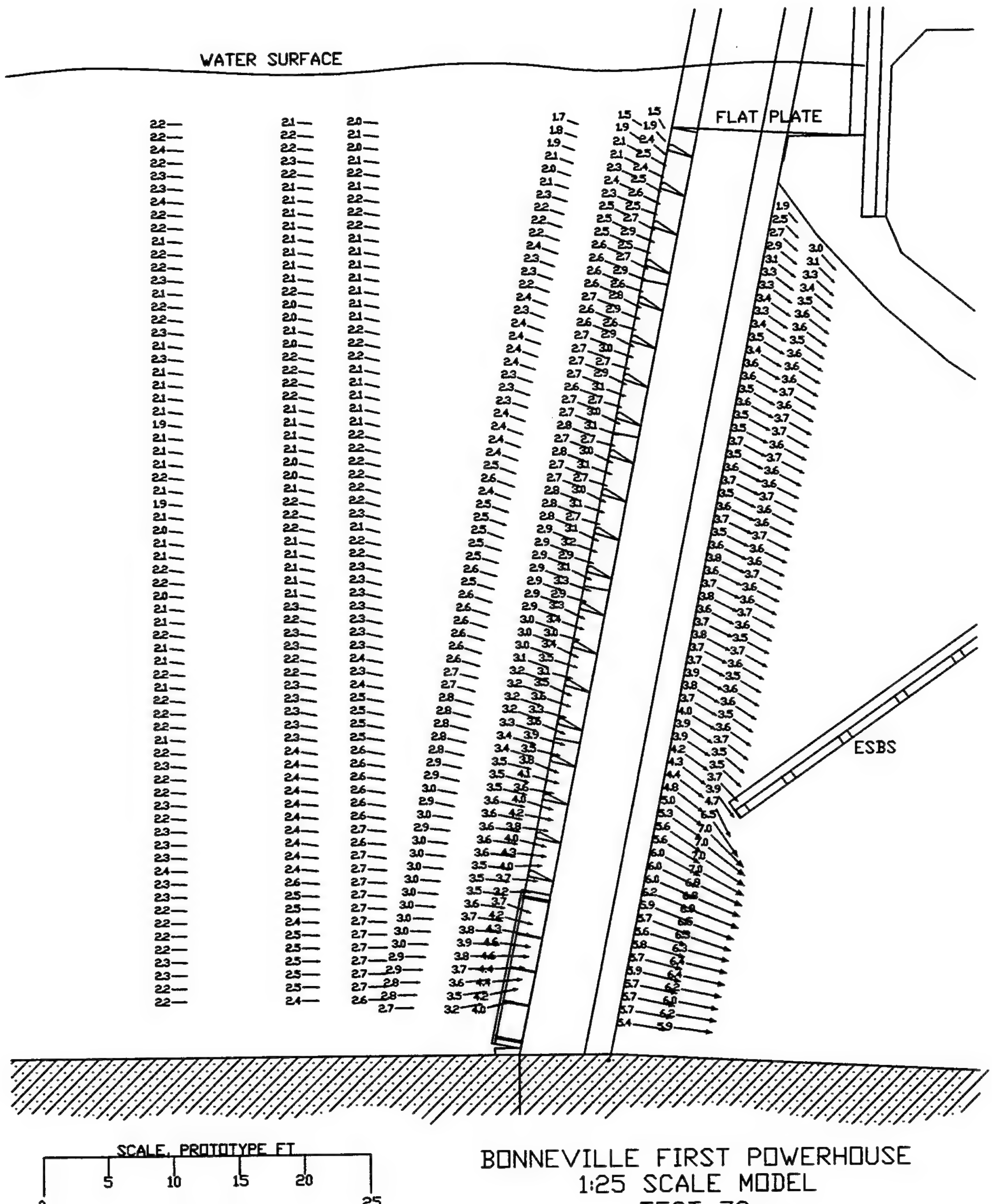


SCALE, PROTOTYPE FT

0 5 10 15 20 25

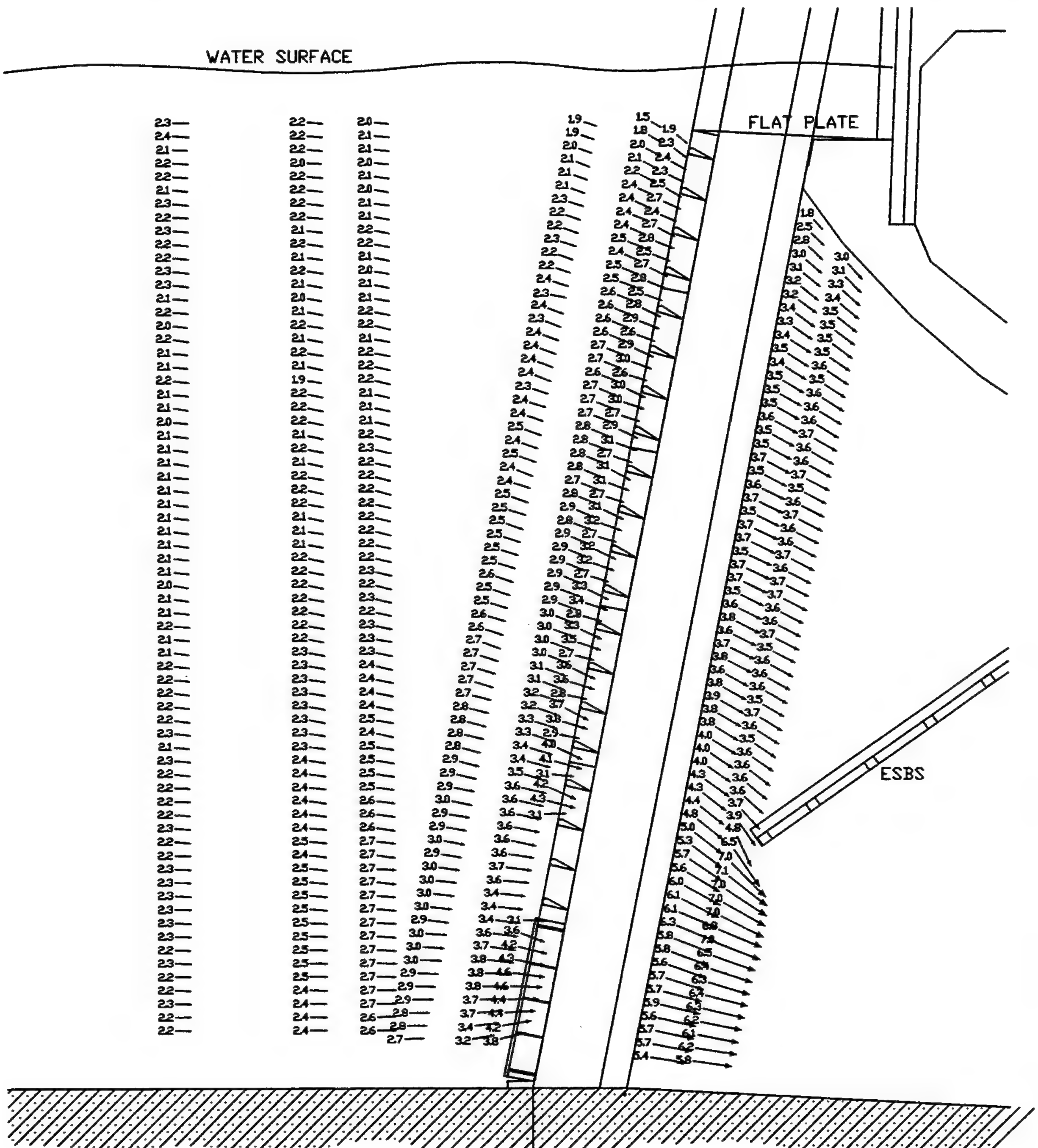
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BITEST77.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 77
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH STREAMLINED TRASHRACK CONFIG 6
FLAT PLATE ROOF EXTENSION IN PLACE



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST78.DWG

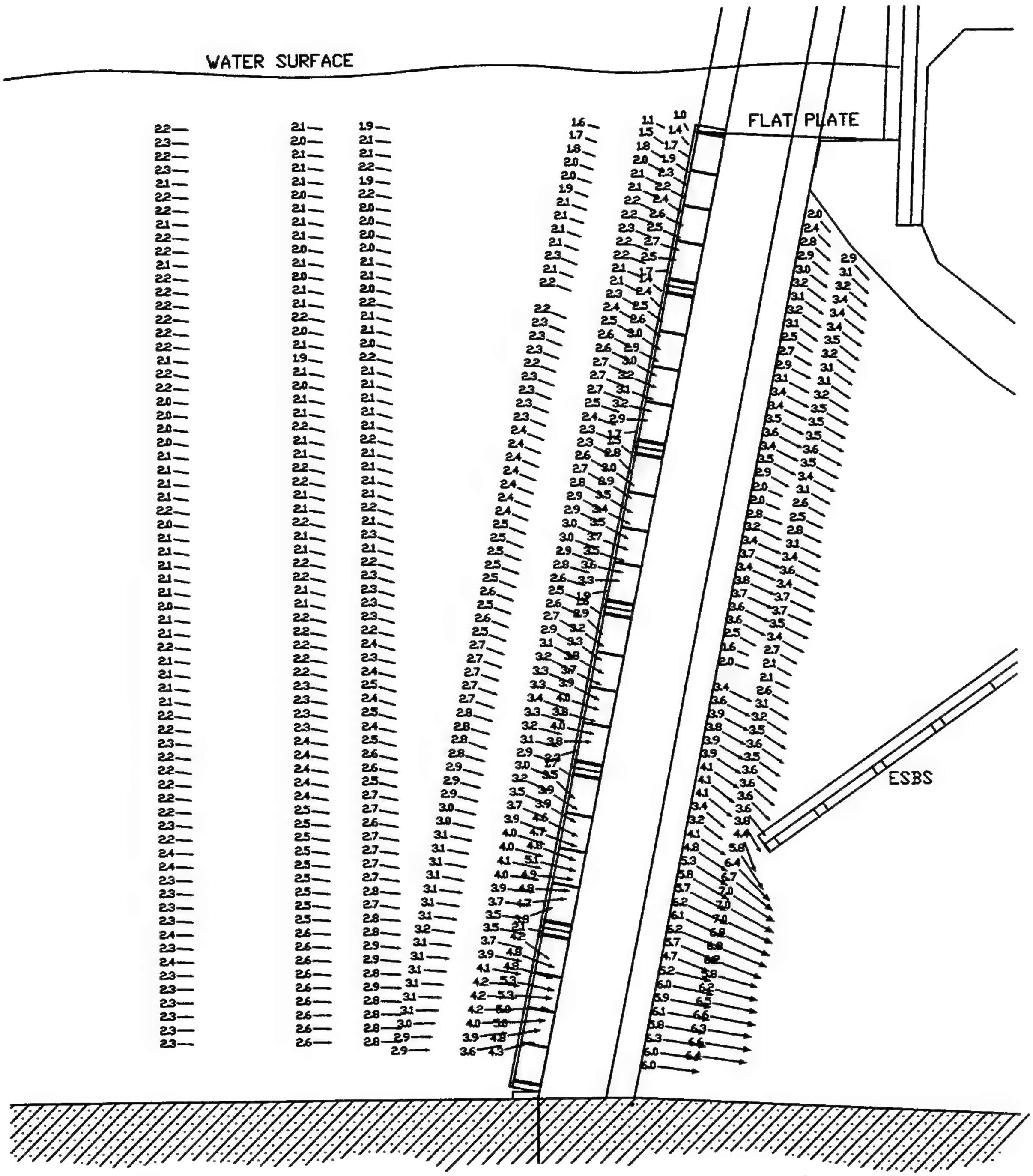
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 78
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH STREAMLINED TRASHRACK CONFIG 6
FLAT PLATE ROOF EXTENSION IN PLACE



SCALE, PROTOTYPE FT
0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST79.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 79
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH STREAMLINED TRASHRACK CONFIG 7
FLAT PLATE ROOF EXTENSION IN PLACE

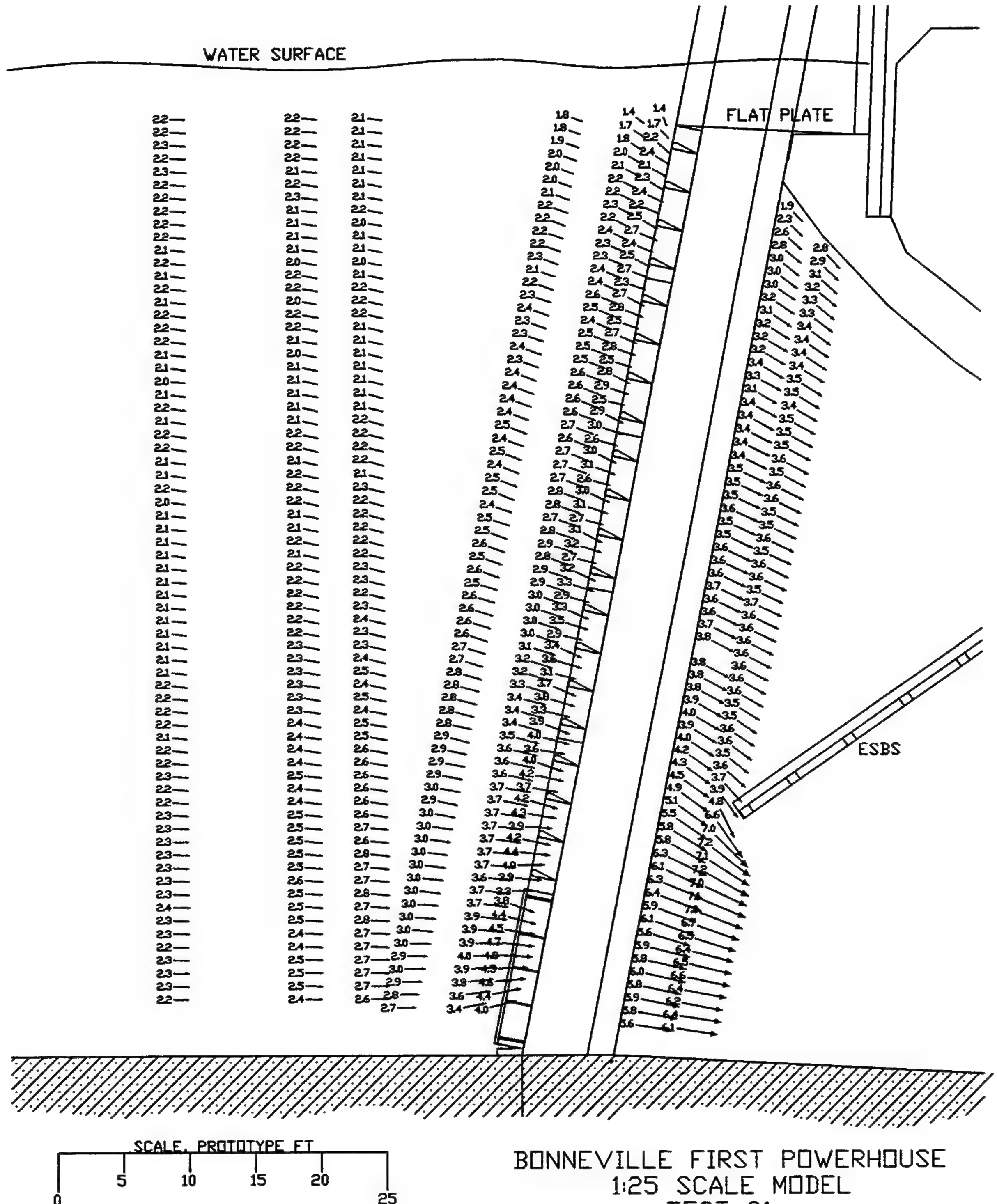


SCALE, PROTOTYPE FT

0 5 10 15 20 25

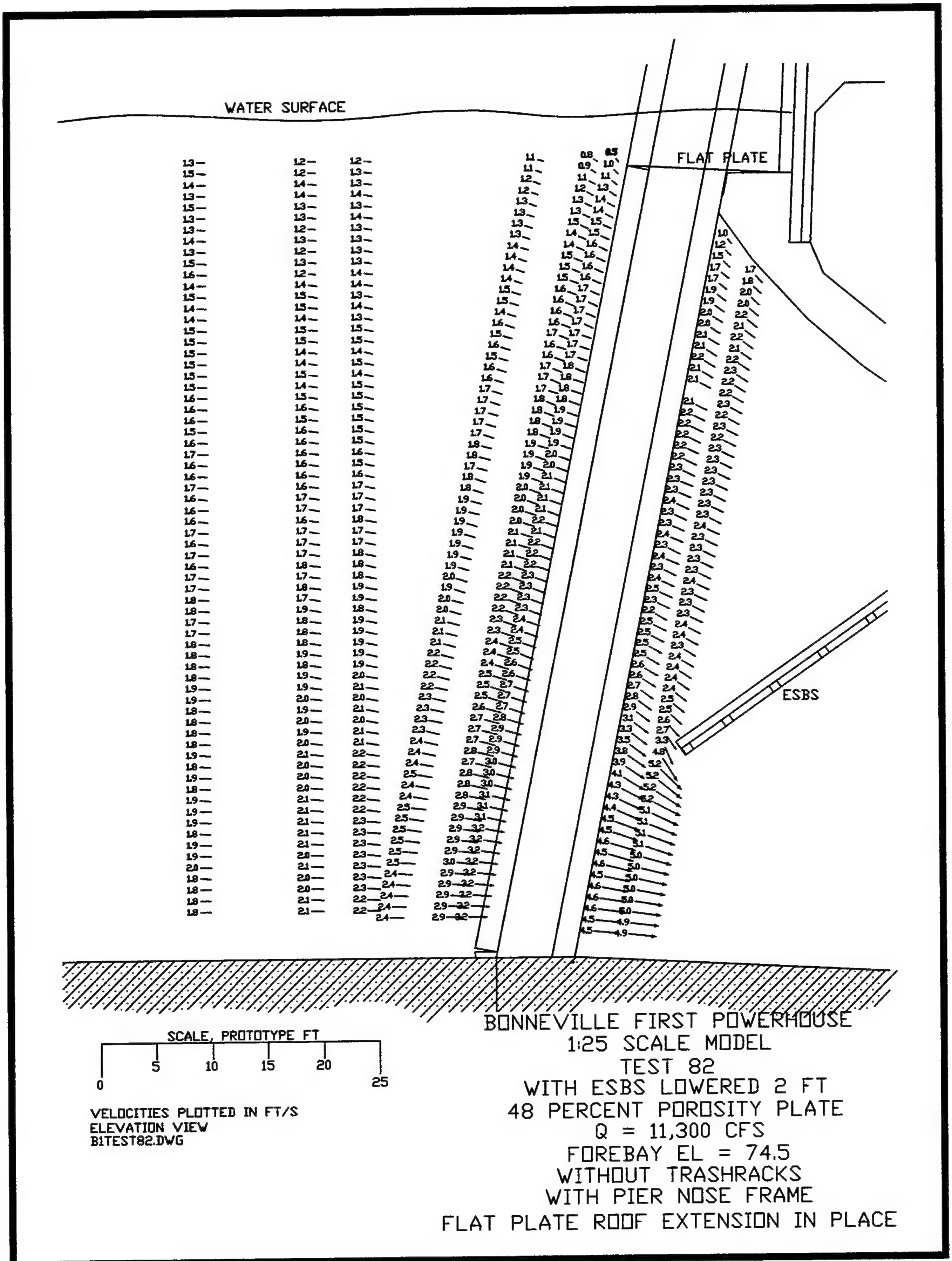
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST80.DWG

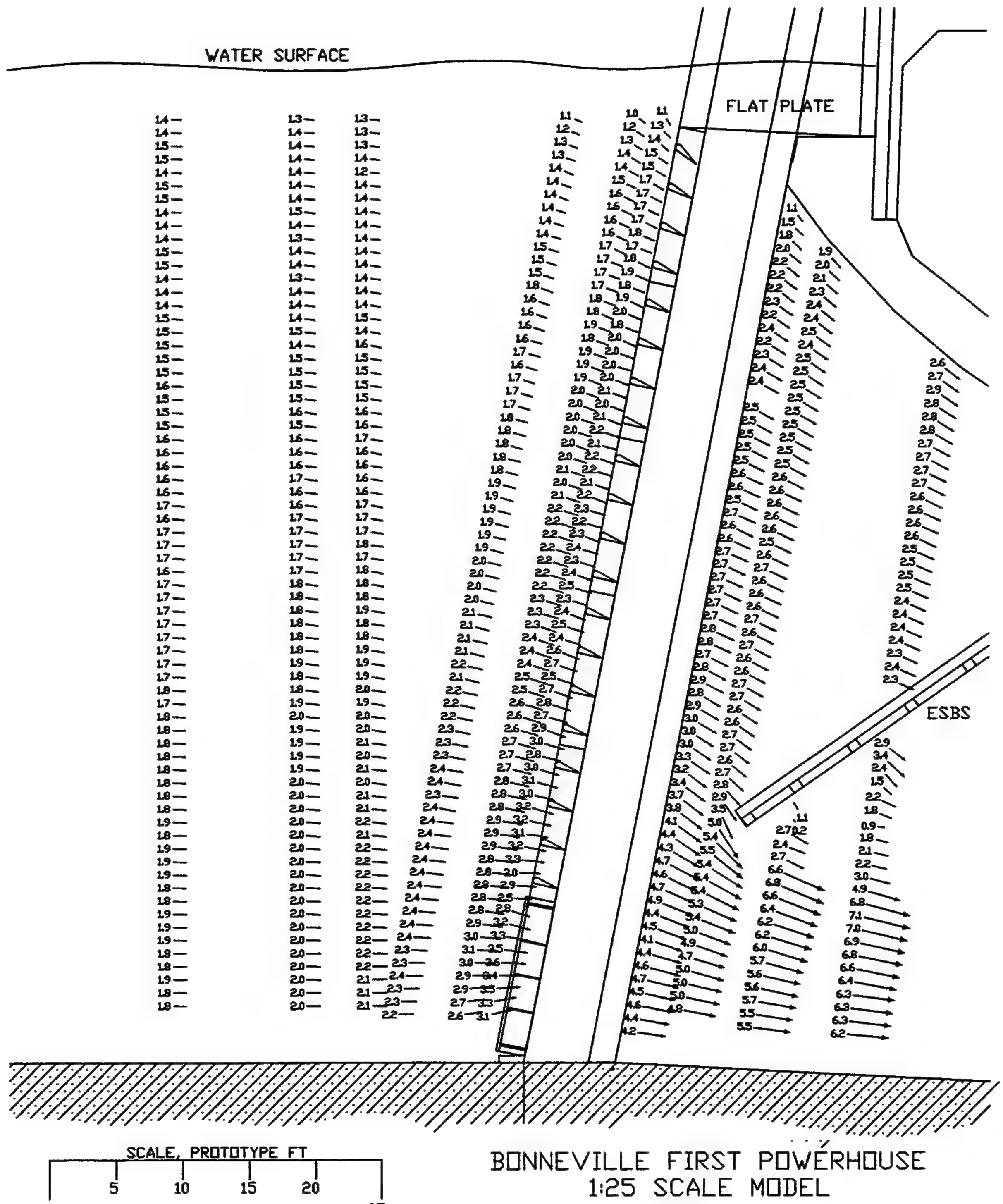
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 80
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH NORMAL TRASHRACKS MOVED TO END OF PIER
FLAT PLATE ROOF EXTENSION IN PLACE



VELOCITIES PLOTTED INFT/S
ELEVATION VIEW
B1TEST81.DWG

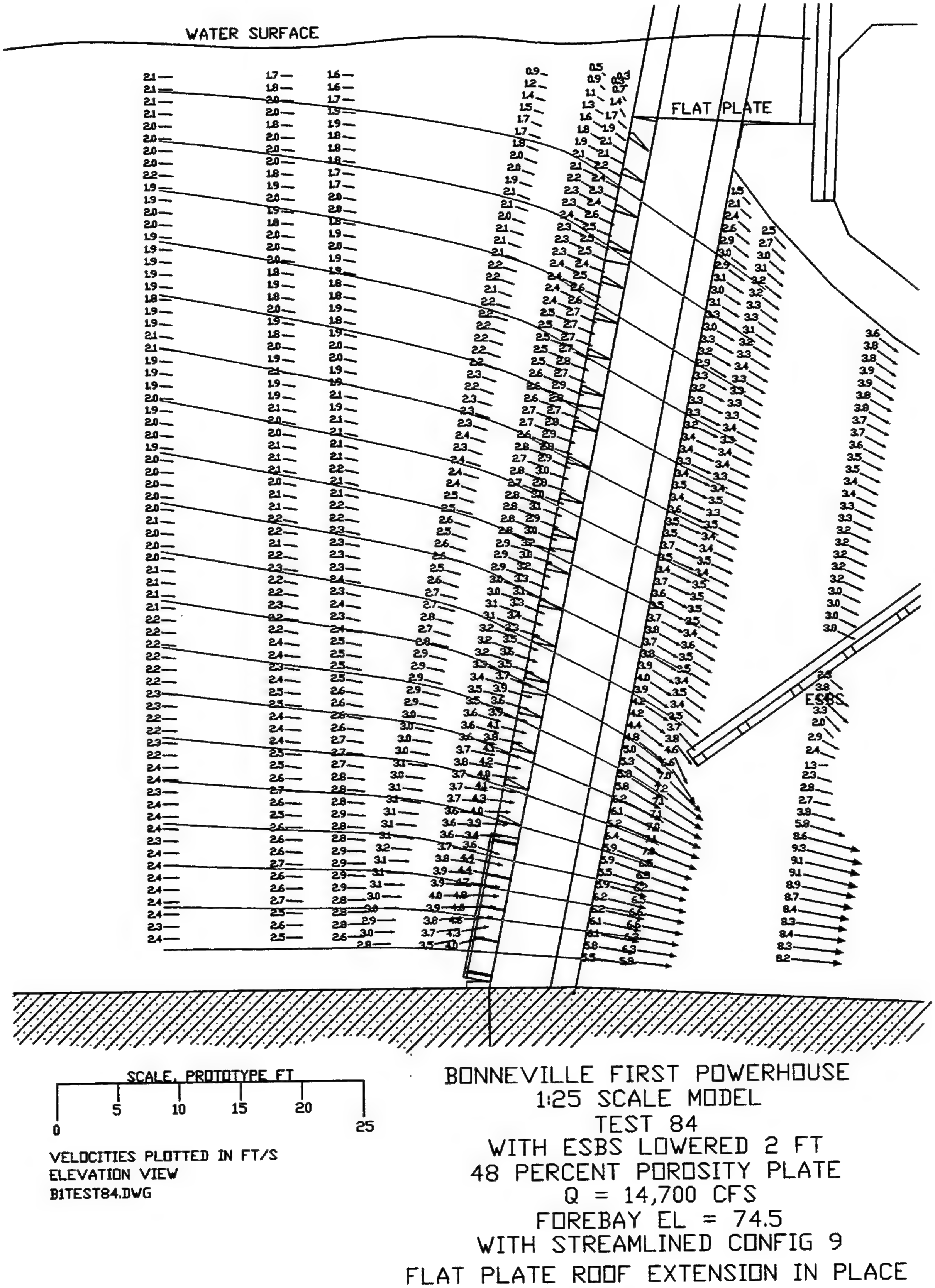
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 81
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH STREAMLINED CONFIG 8
FLAT PLATE ROOF EXTENSION IN PLACE


WATER SURFACE
FLAT PLATE
ESBS
SCALE, PROTOTYPE FT
0
5
10
15
20
25
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST82.DWG
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 82
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
WITHOUT TRASHRACKS
WITH PIER NOSE FRAME
FLAT PLATE ROOF EXTENSION IN PLACE



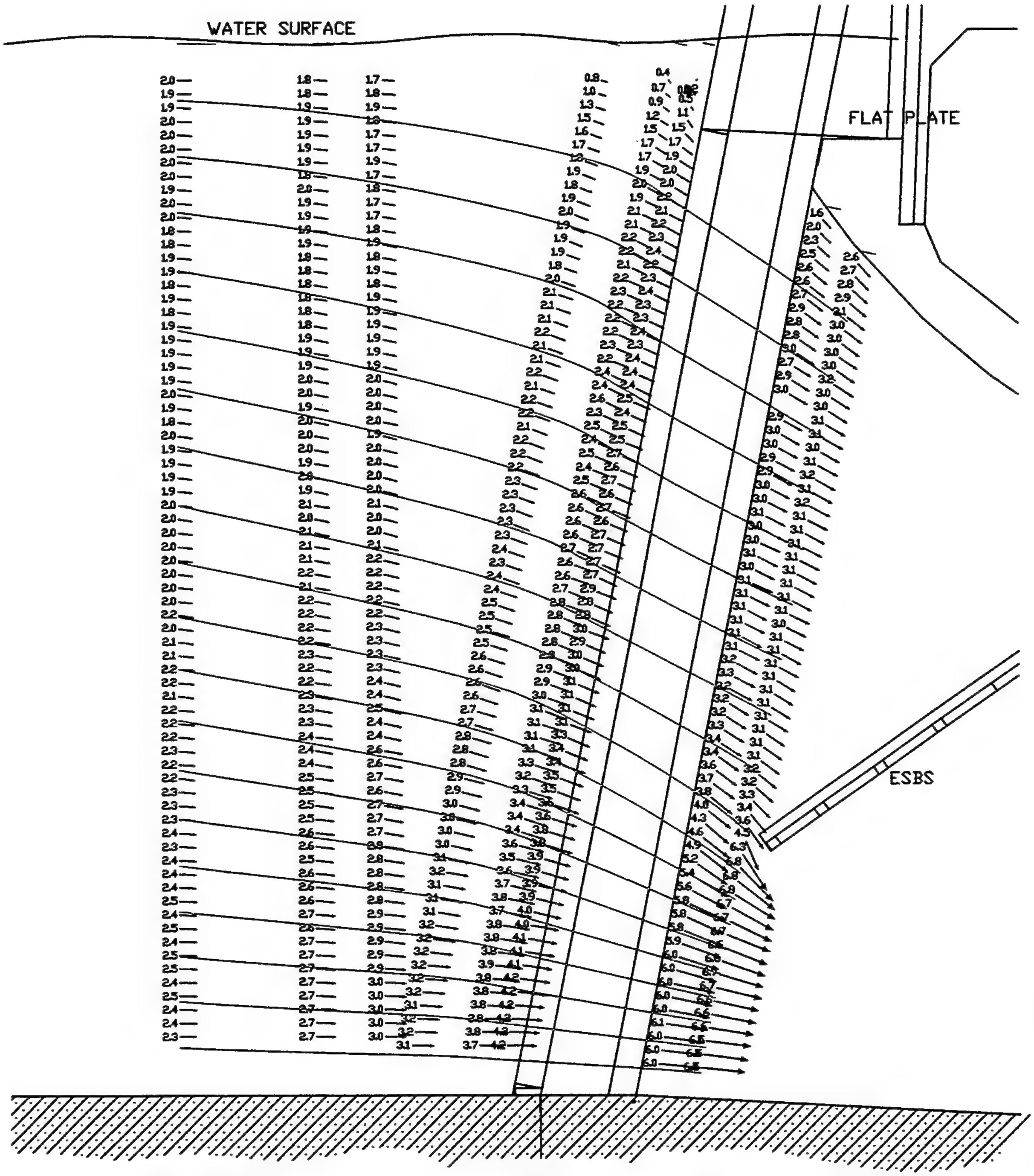
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST83.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 83
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
WITH STREAMLINED CONFIG 9
FLAT PLATE ROOF EXTENSION IN PLACE



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST84.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 84
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH STREAMLINED CONFIG 9
FLAT PLATE ROOF EXTENSION IN PLACE

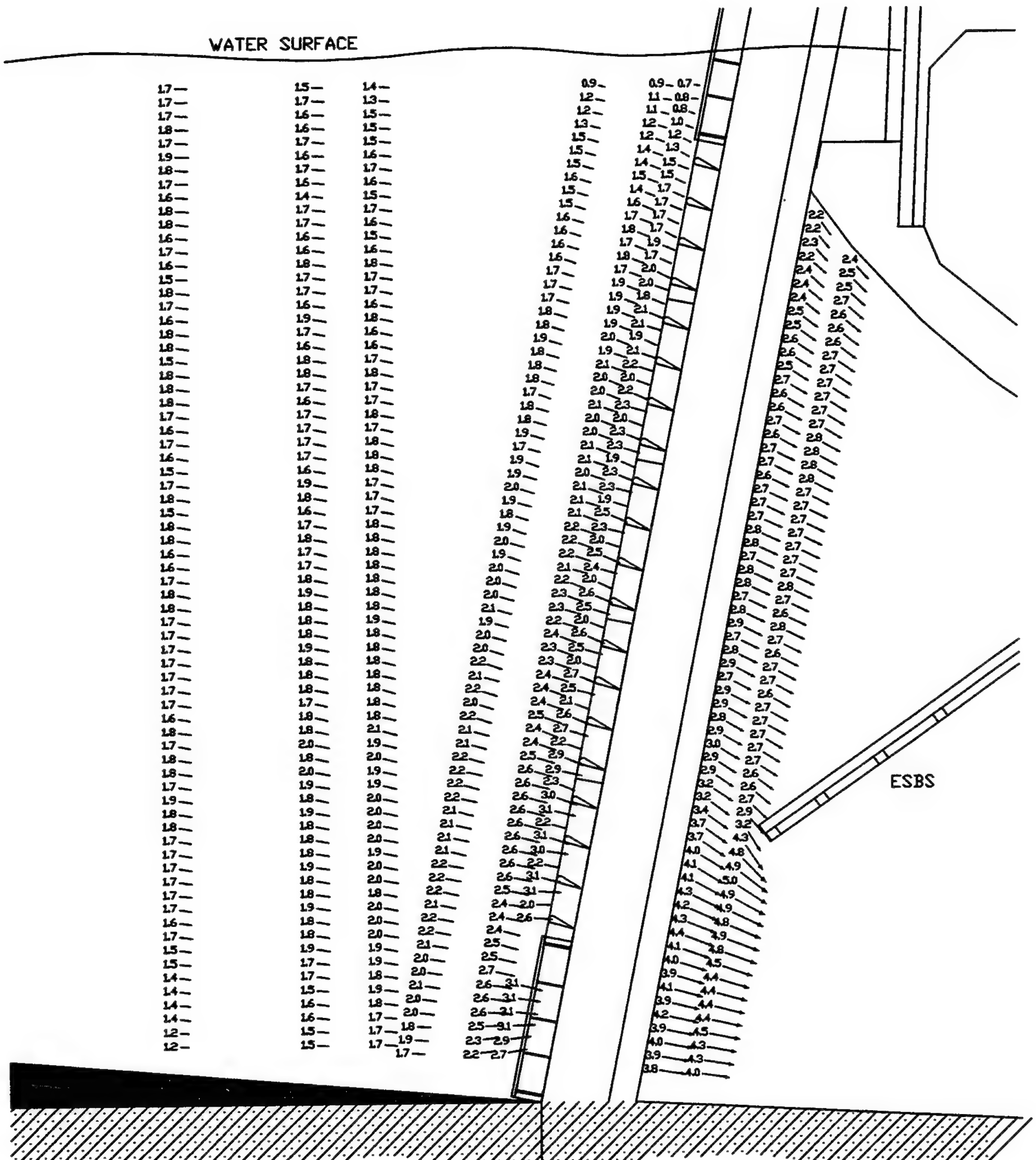


SCALE, PROTOTYPE FT

0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
B1TEST85.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 85
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 14,700 CFS
FOREBAY EL = 74.5
WITH UPSTREAM TRASHRACK FRAME
FLAT PLATE ROOF EXTENSION IN PLACE



SCALE, PROTOTYPE FT

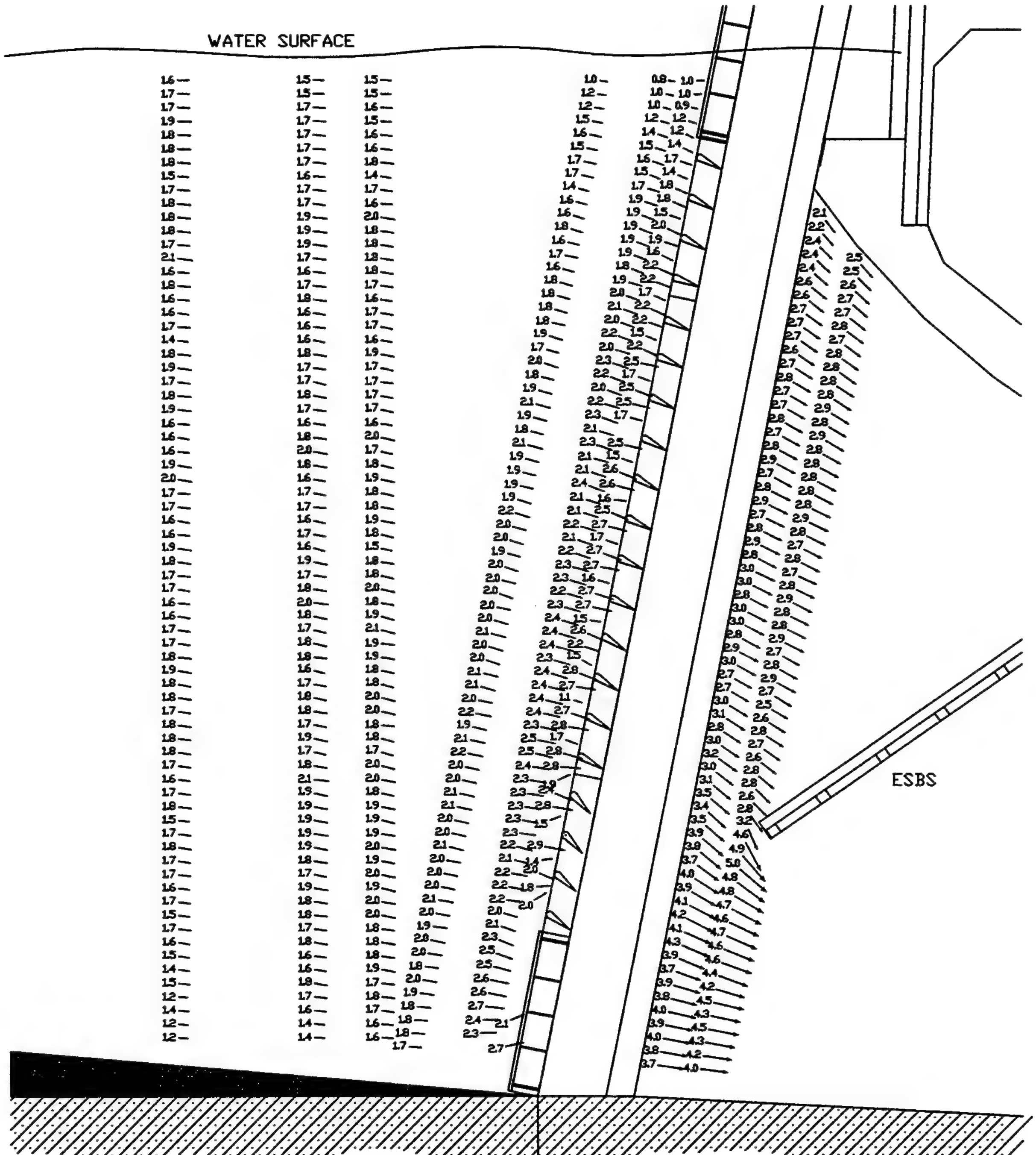
0 5 10 15 20 25

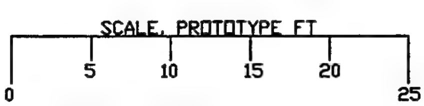
VELOCITIES PLOTTED IN FT/S

ELEVATION VIEW

BTST124.DWG

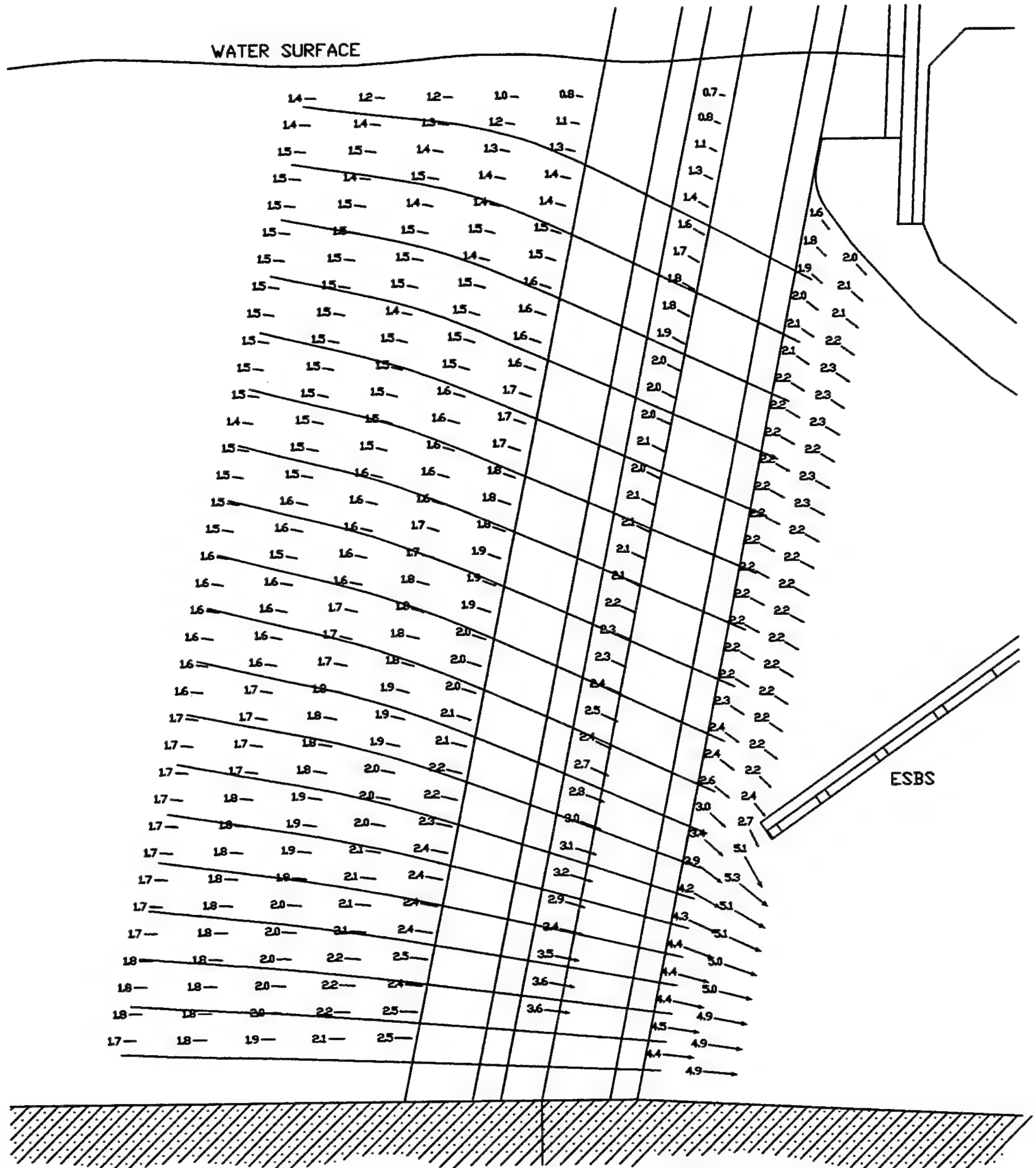
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 124
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
UNIT EIGHT TOPO IN PLACE
STREAMLINED TRASHRACKS AT PIER NOSE
STREAMLINED TRASHRACKS ANGLED AT 12 DEG





VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST125.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 125
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
UNIT EIGHT TOPO IN PLACE
REVERSE TRASHRACK CONFIGURATION #13

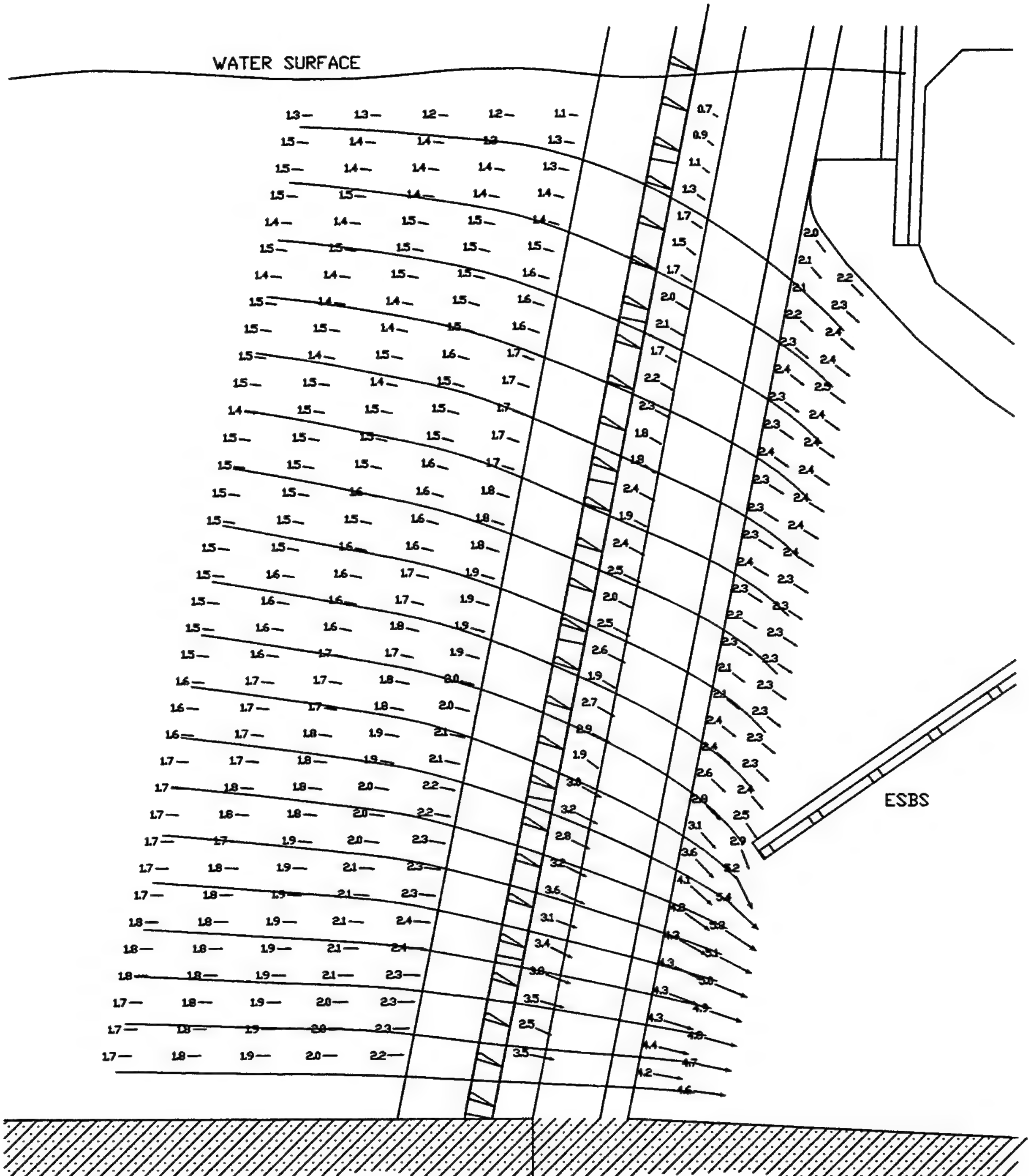


SCALE, PROTOTYPE FT

0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST112.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 112
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
10 FT PIER EXTENSION
WITHOUT TRASHRACKS

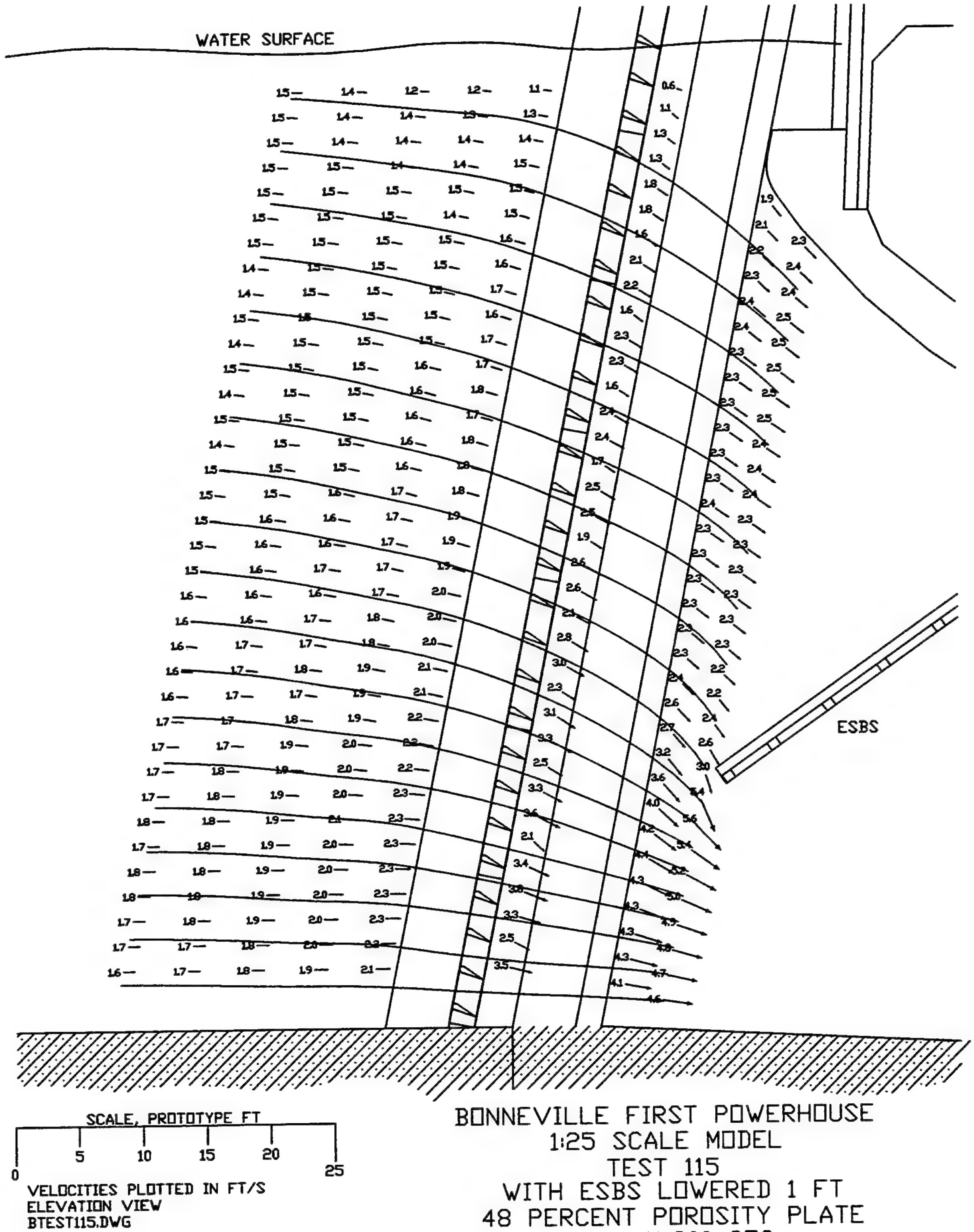


SCALE, PROTOTYPE FT

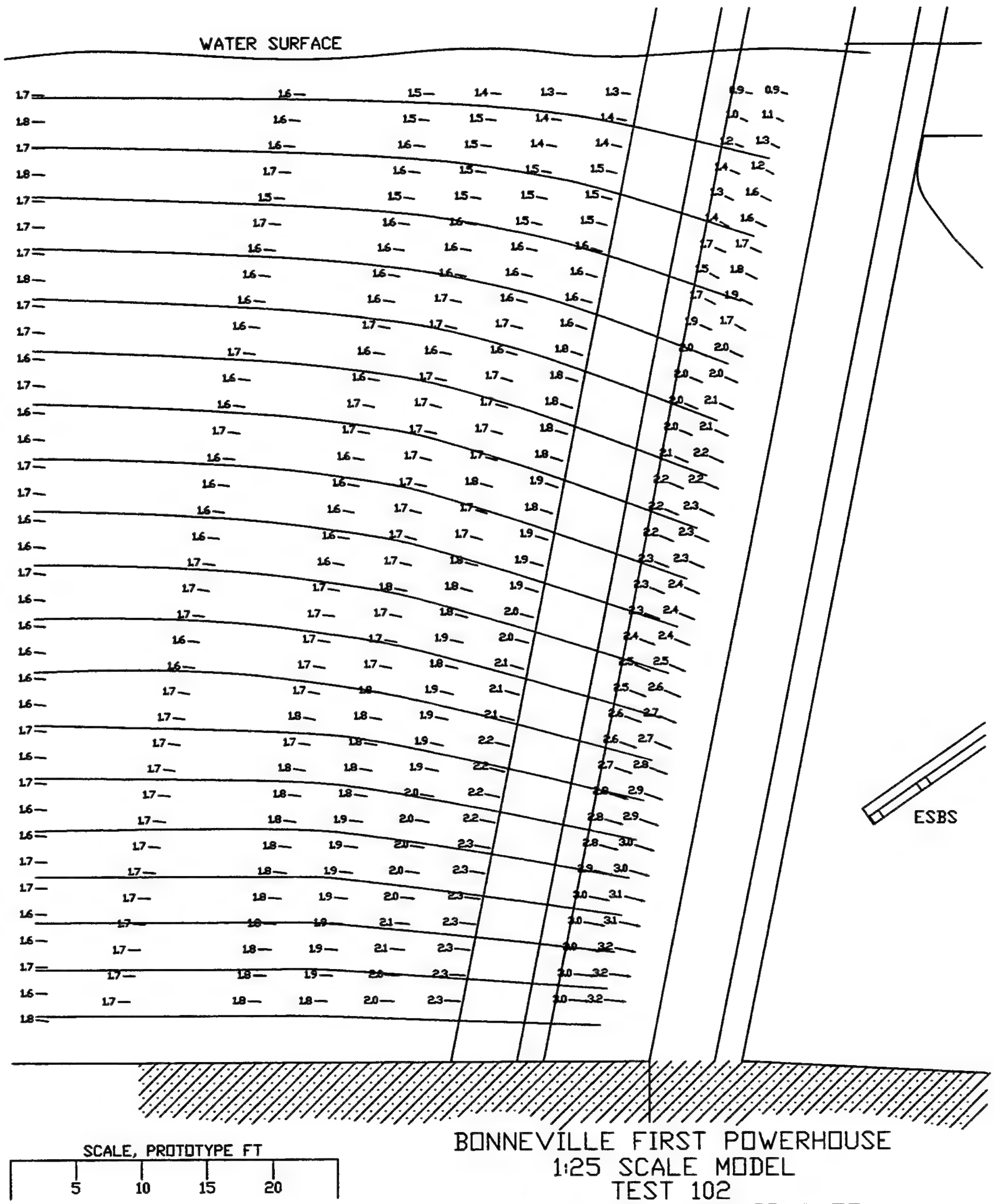
0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST114.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 114
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
10 FT PIER EXTENSION
TRASHRACK MEMBERS ANGLED @ 13.7 DEG

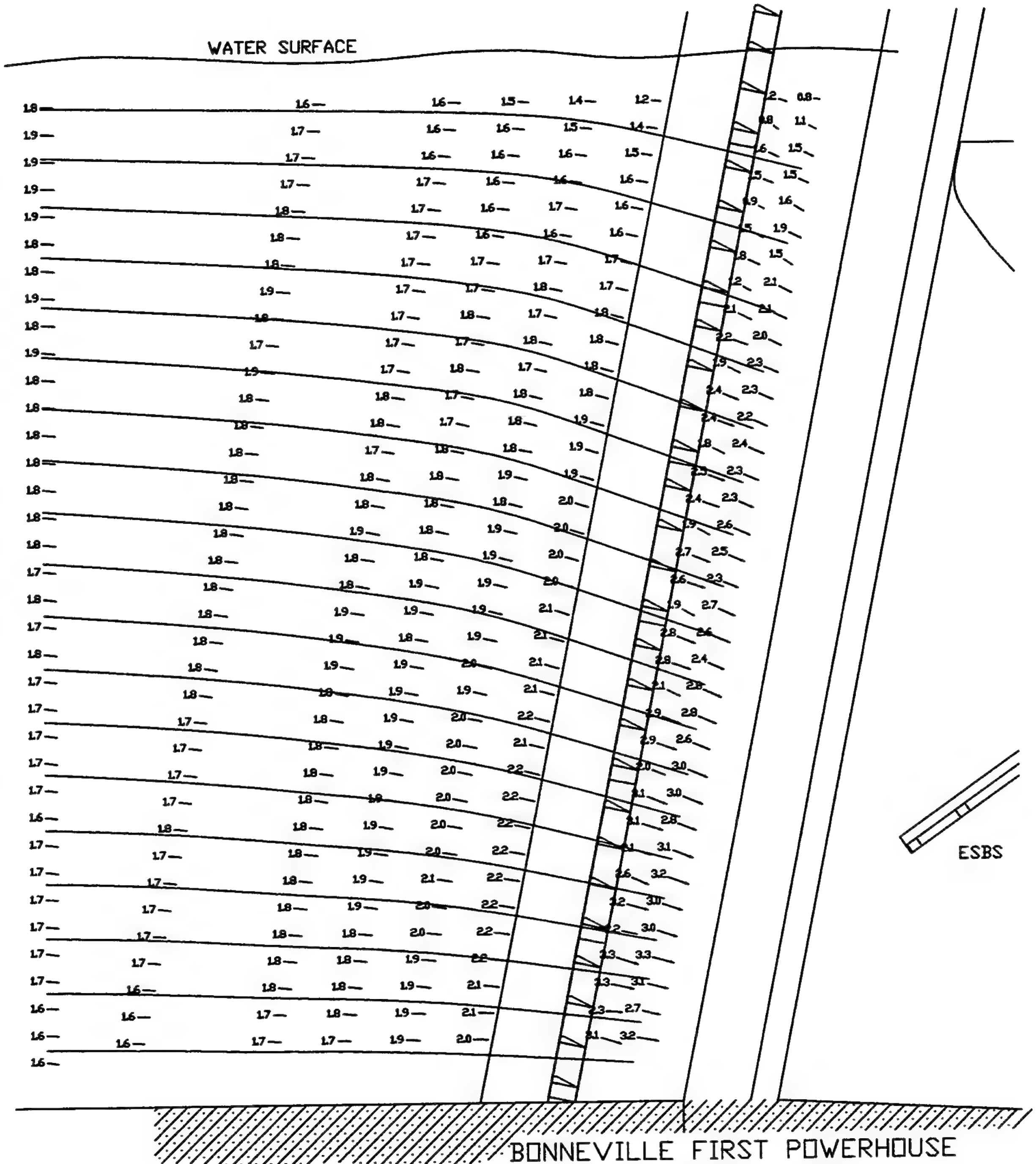


BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 115
WITH ESBS LOWERED 1 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
10 FT PIER EXTENSION
TRASHRACK MEMBERS ANGLED @ 15.7 DEG



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST102.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 102
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
15 FT PIER EXTENSION
WITHOUT TRASHRACKS

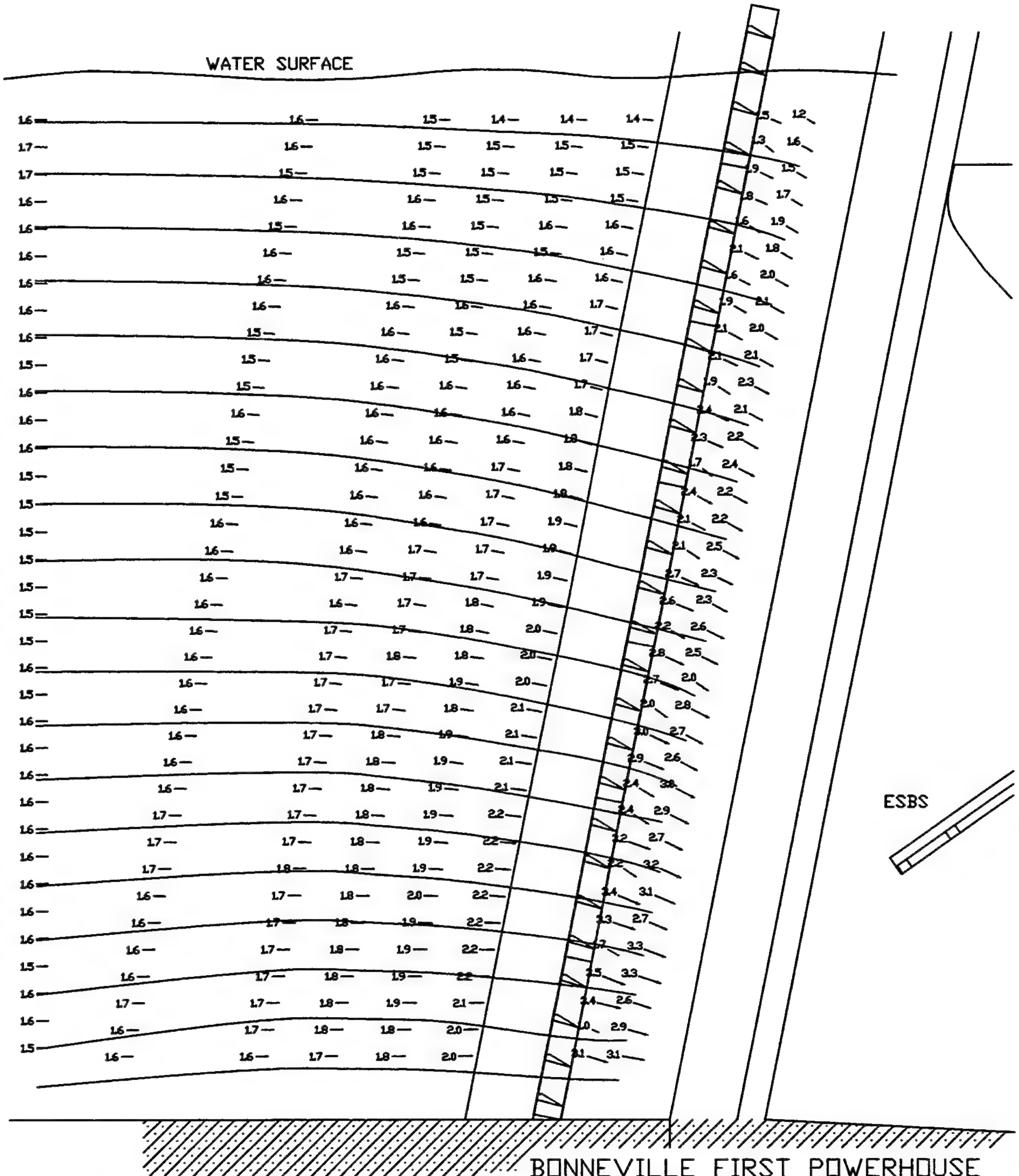


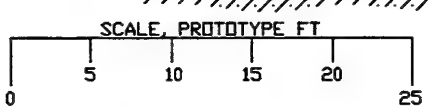
SCALE, PROTOTYPE FT

0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST103.DWG

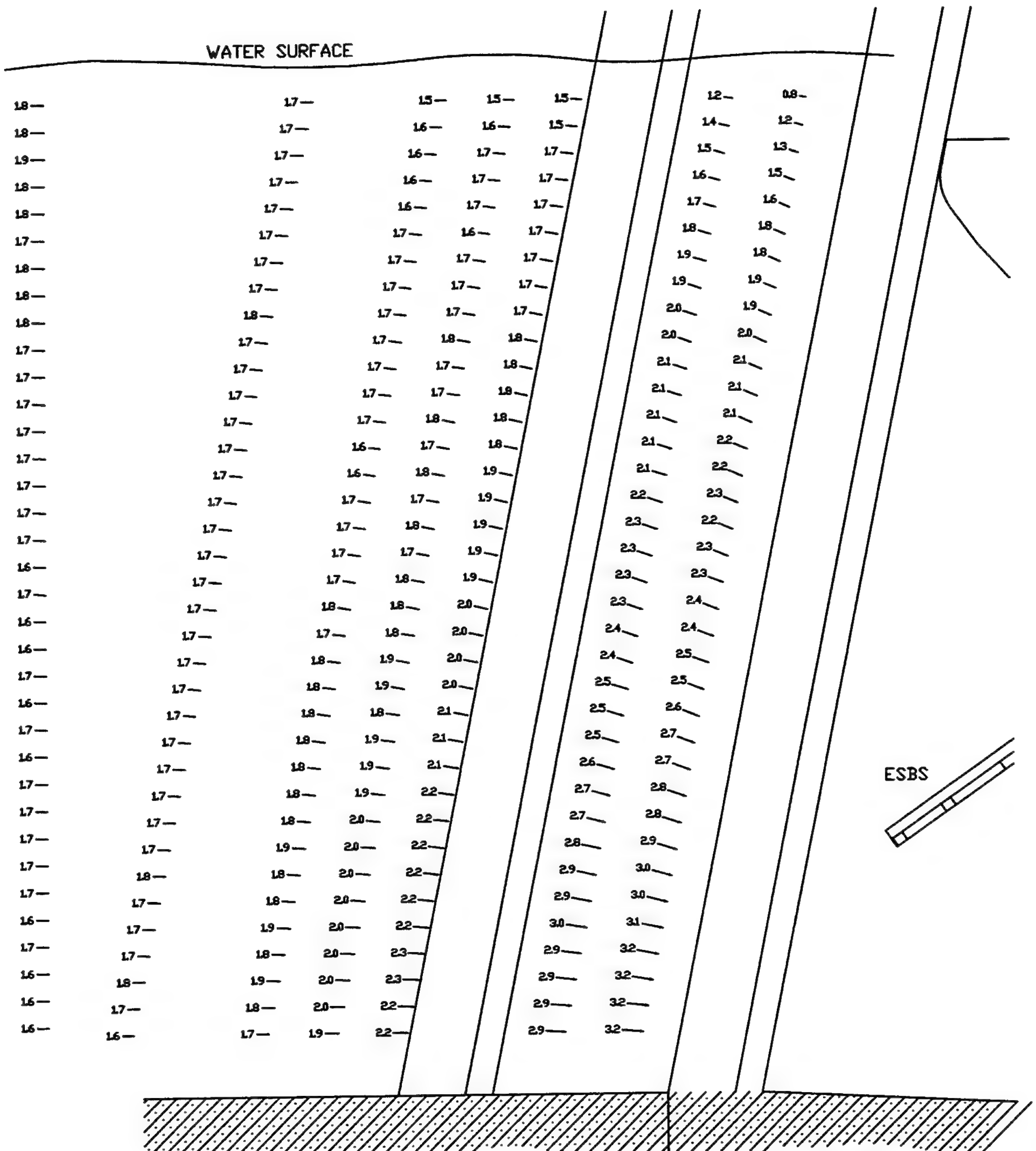
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 103
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
15 FT PIER EXTENSION
TRASHRACK MEMBERS ANGLED AT 9 DEG

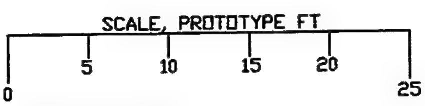




VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST110.DWG

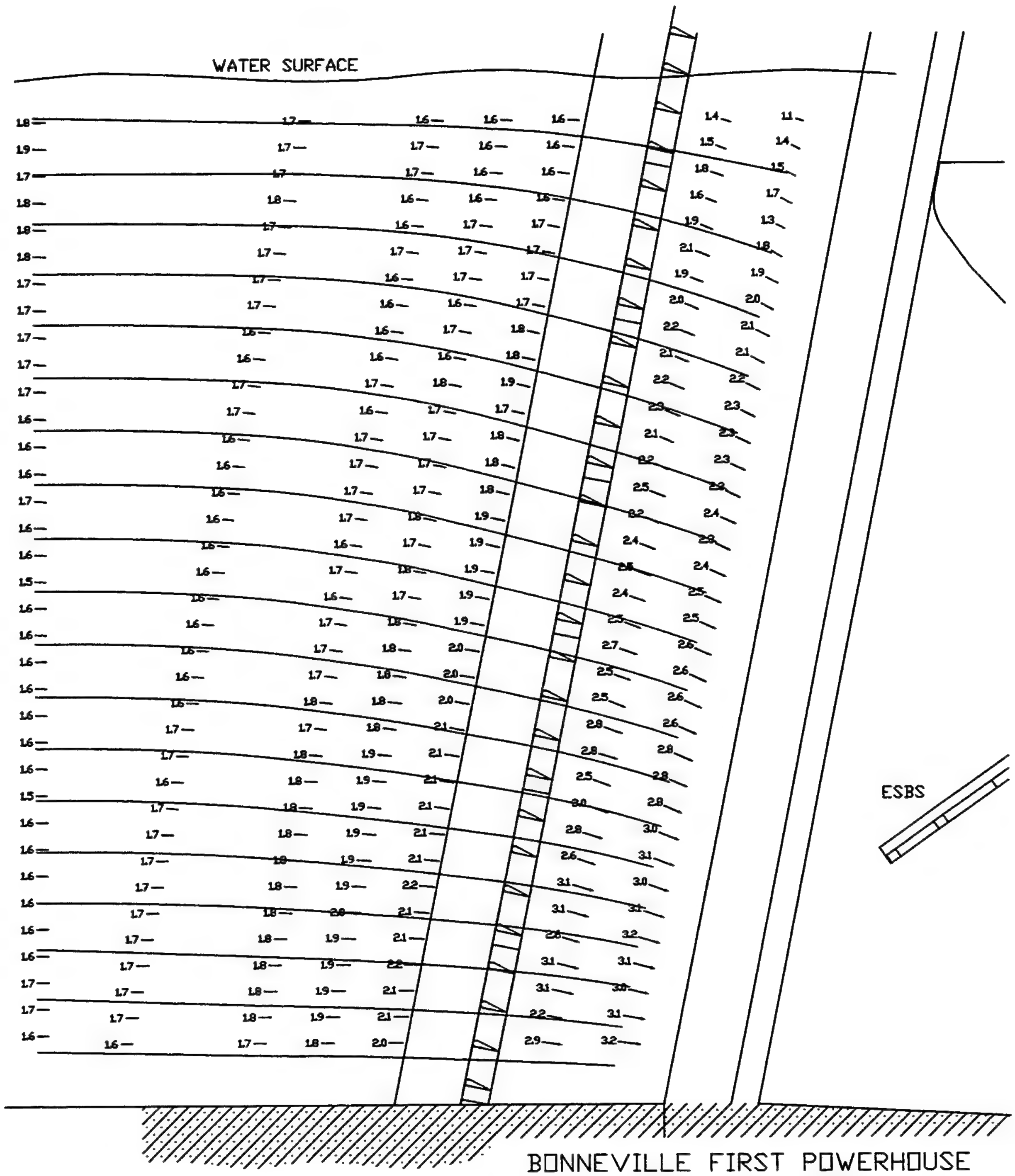
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 110
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
15 FT PIER EXTENSION
TRASHRACK MEMBERS ANGLED AT 12 DEG





VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTST100F.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 100
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
20 FT PIER EXTENSION

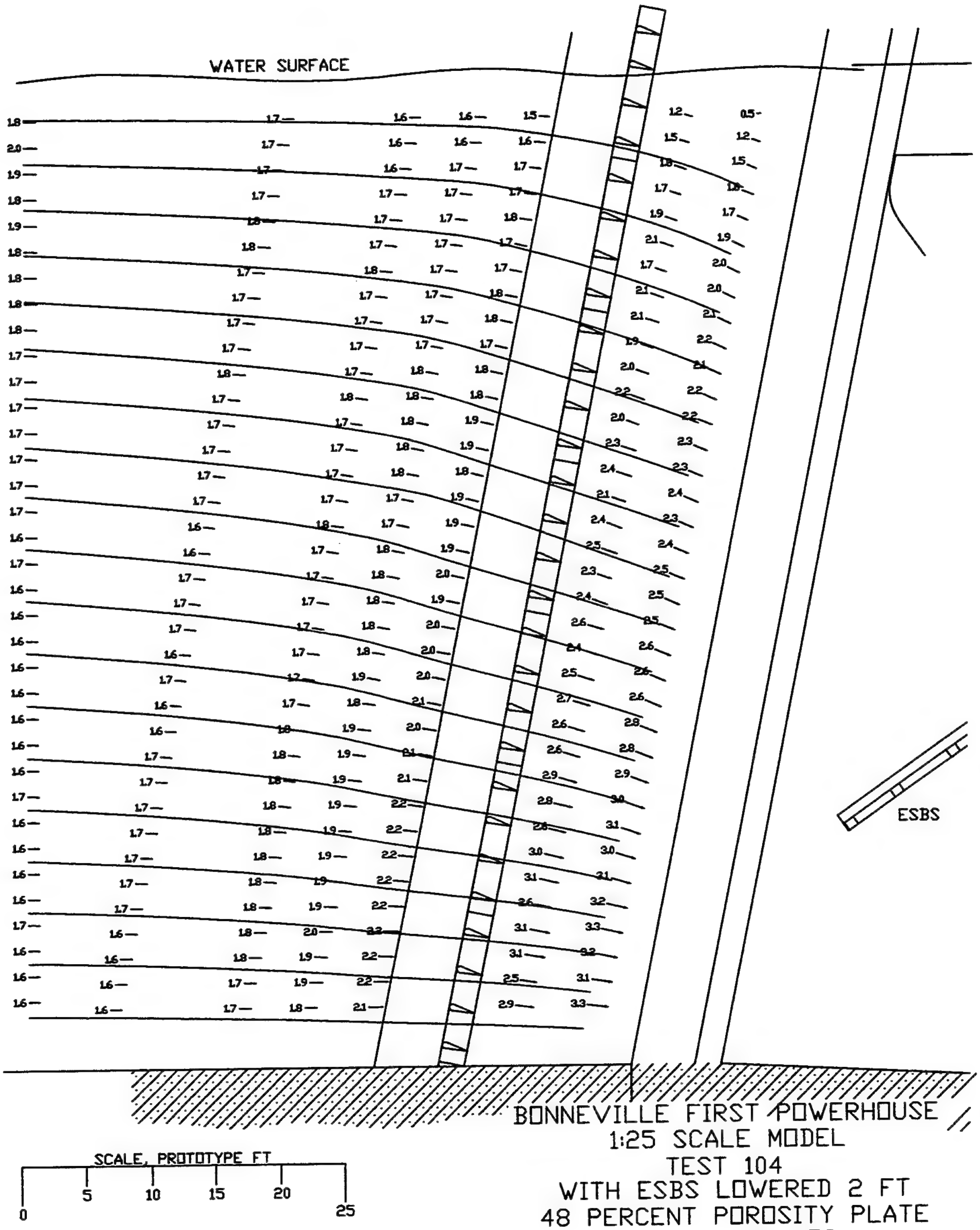


SCALE, PROTOTYPE FT

0 5 10 15 20 25

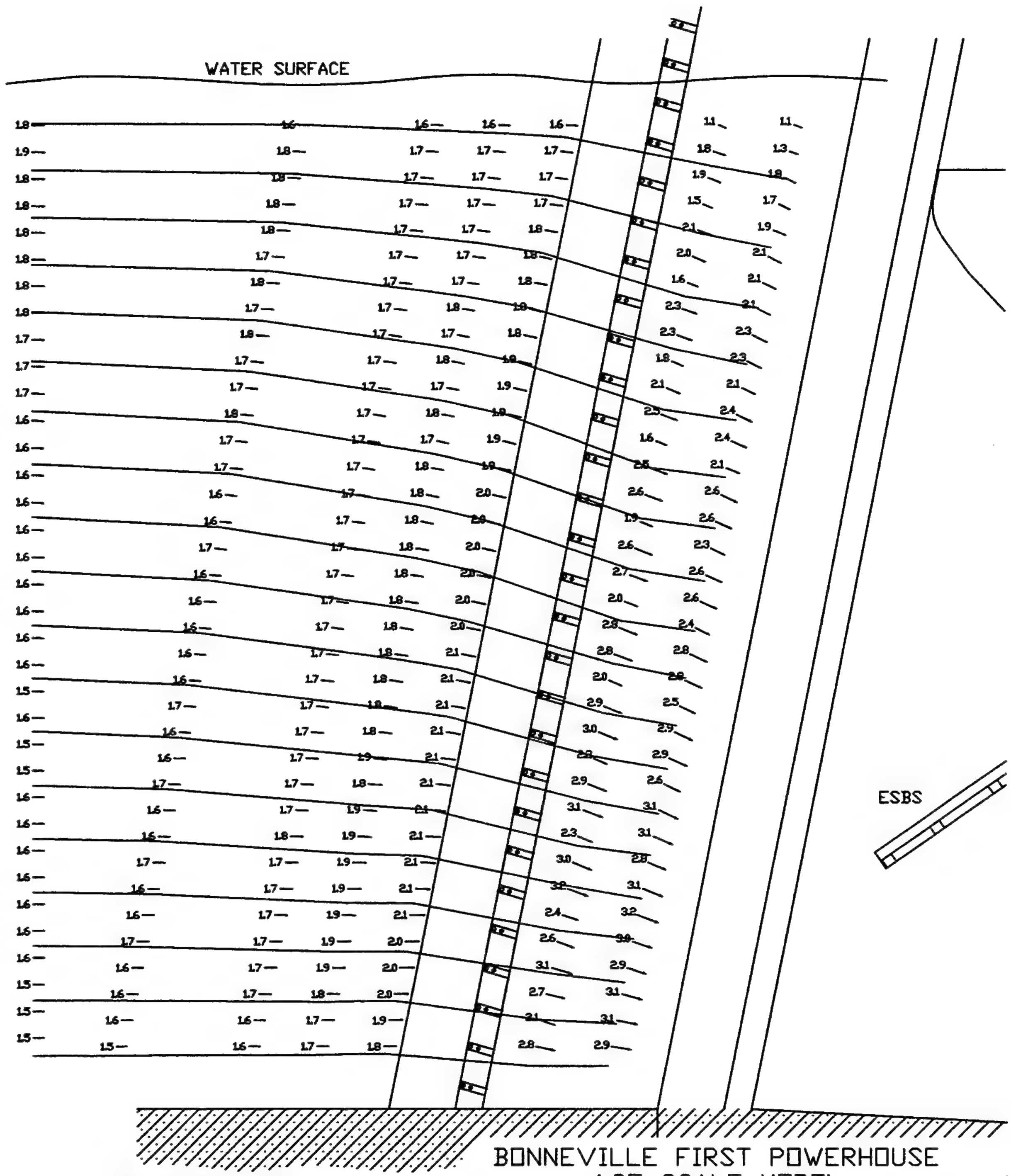
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST101.DWG

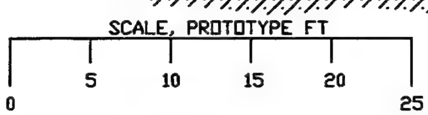
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 101
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
20 FT PIER EXTENSION
TRASHRACK MEMBERS ANGLED @ 9 DEG



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST104.DWG

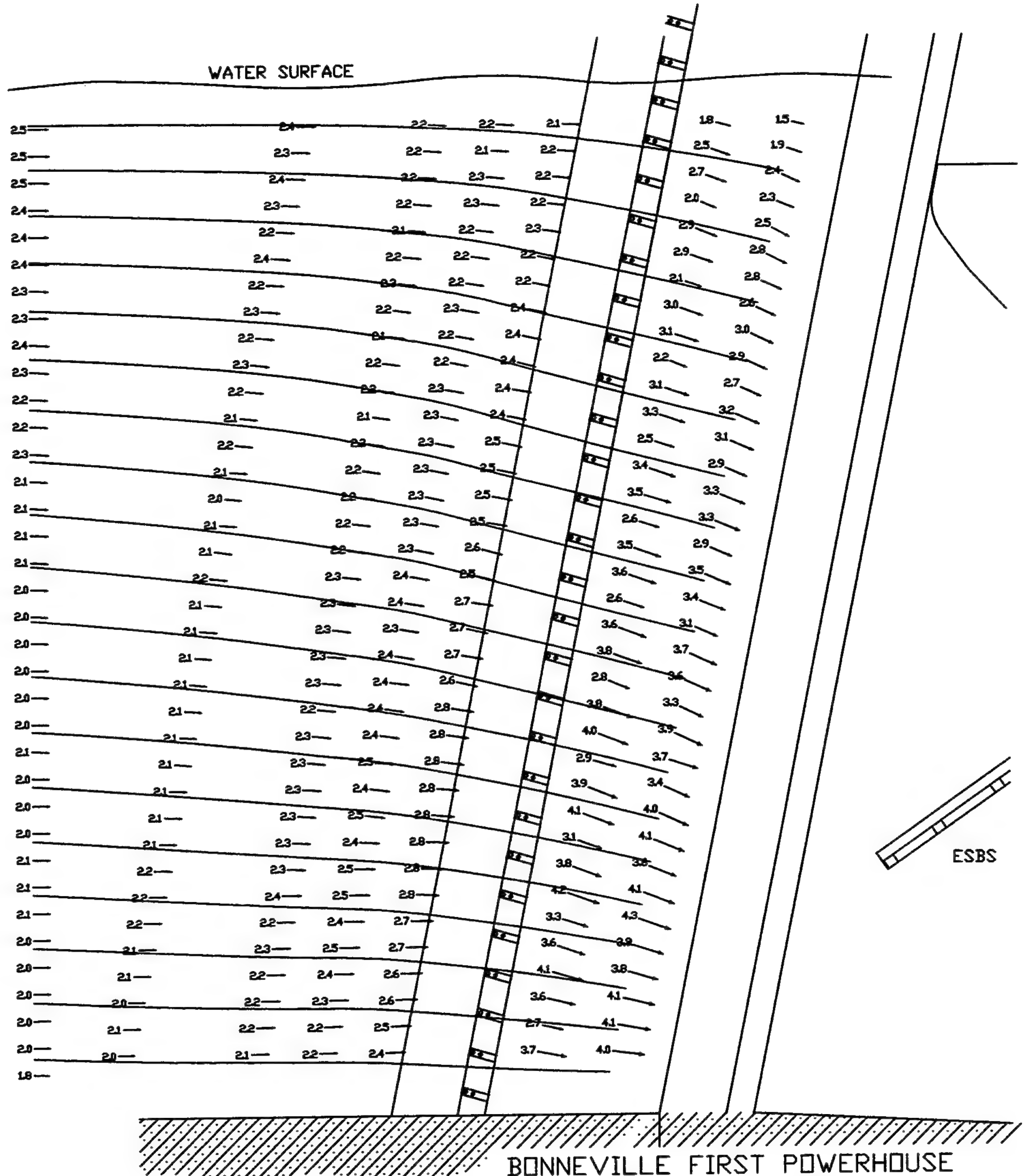
BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 104
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
20 FT PIER EXTENSION
TRASHRACK MEMBERS ANGLED @ 5.1 DEG





VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST105.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 105
WITH ESBS LOWERED 2 FT
BOX BEAM TRASHRACKS
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
20 FT PIER EXTENSION
TRASHRACK MEMBERS ANGLED @ 5.1 DEG

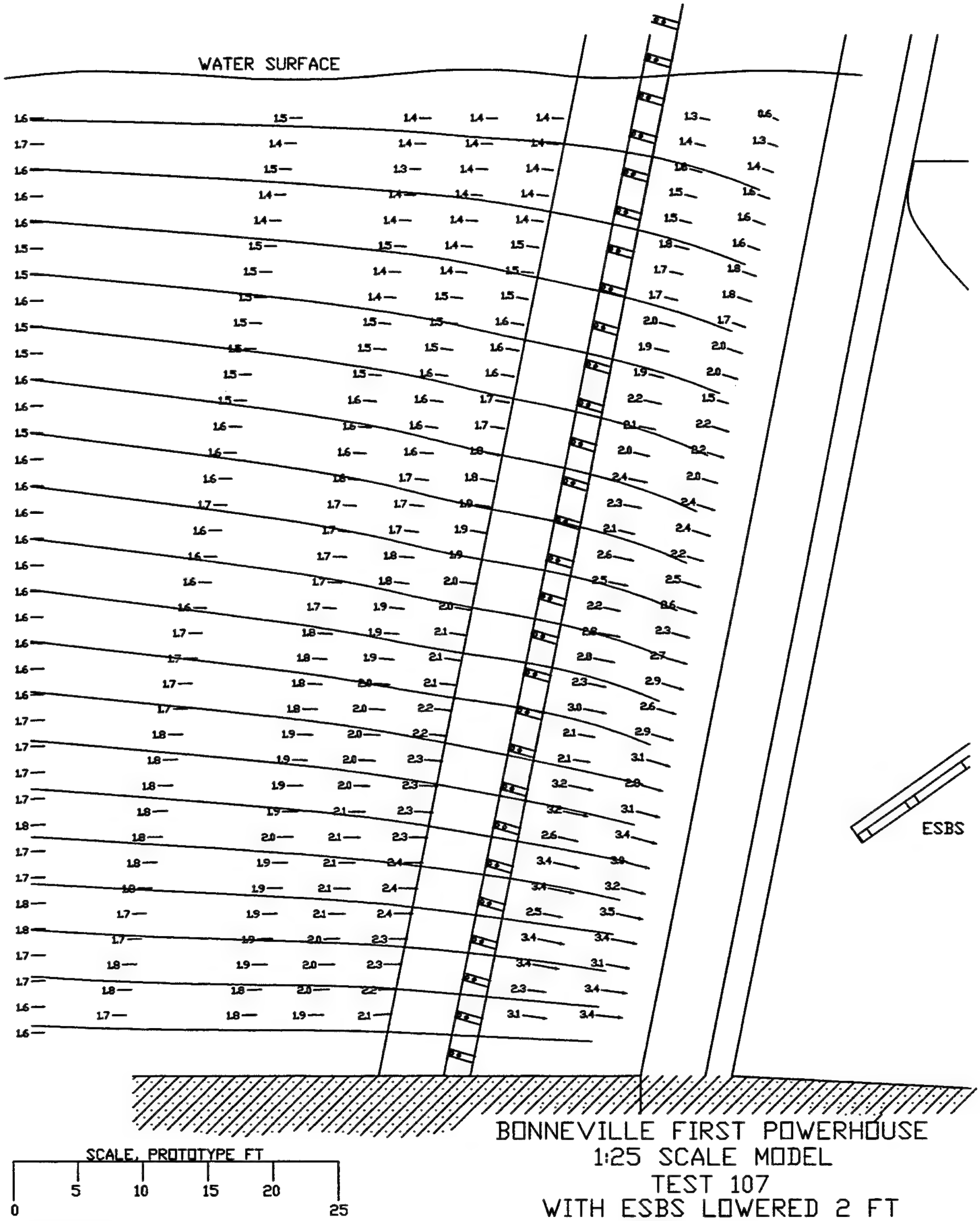


SCALE, PROTOTYPE FT

0 5 10 15 20 25

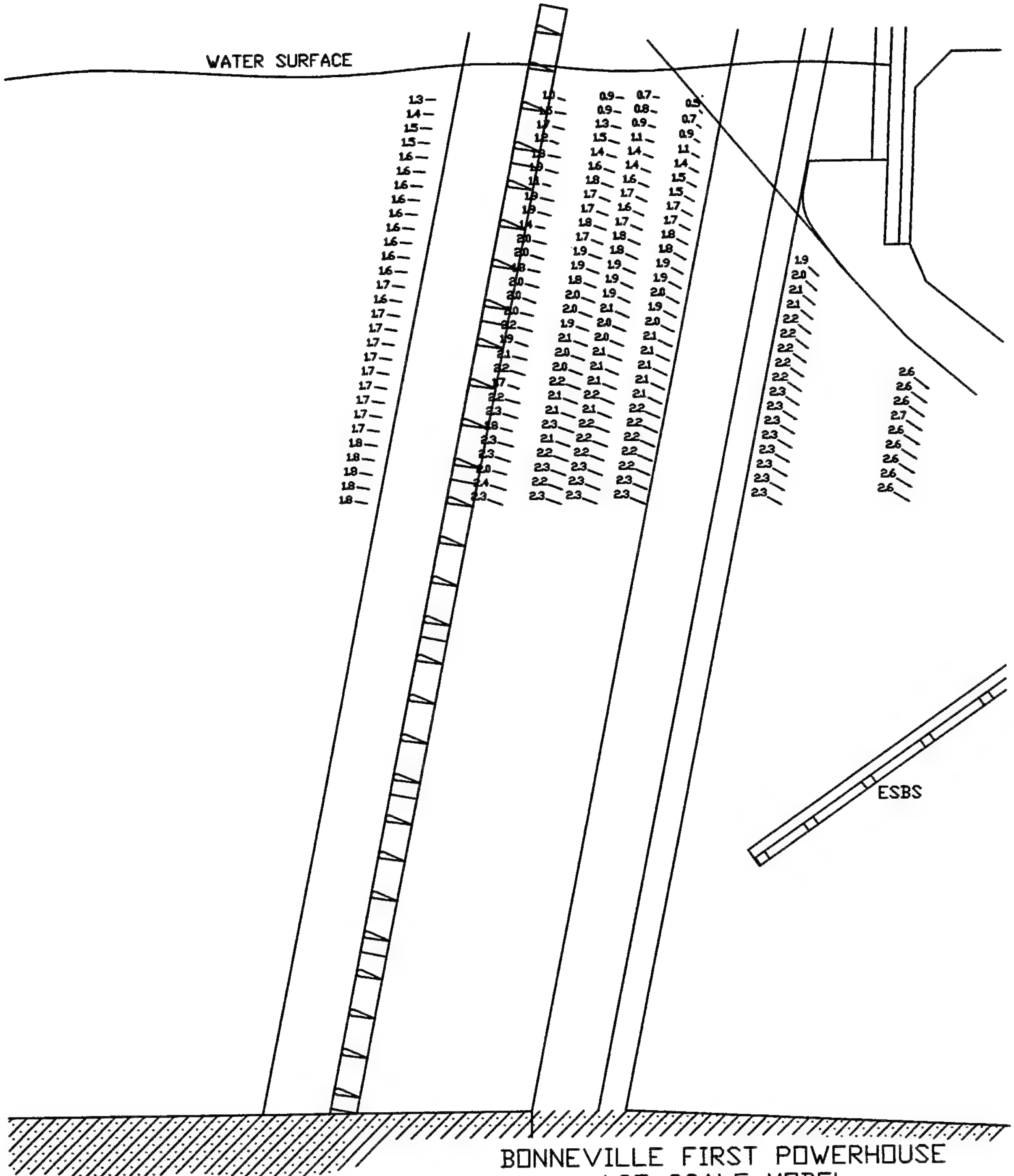
VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST106.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 106
WITH ESBS LOWERED 2 FT
BOX BEAM TRASHRACKS
Q = 14,700 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
20 FT PIER EXTENSION
TRASHRACK MEMBERS ANGLED @ 5.1 DEG



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST107.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 107
WITH ESBS LOWERED 2 FT
BOX BEAM TRASHRACKS
Q = 14,700 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
20 FT PIER EXTENSION
TRASHRACK MEMBERS HORIZONTAL

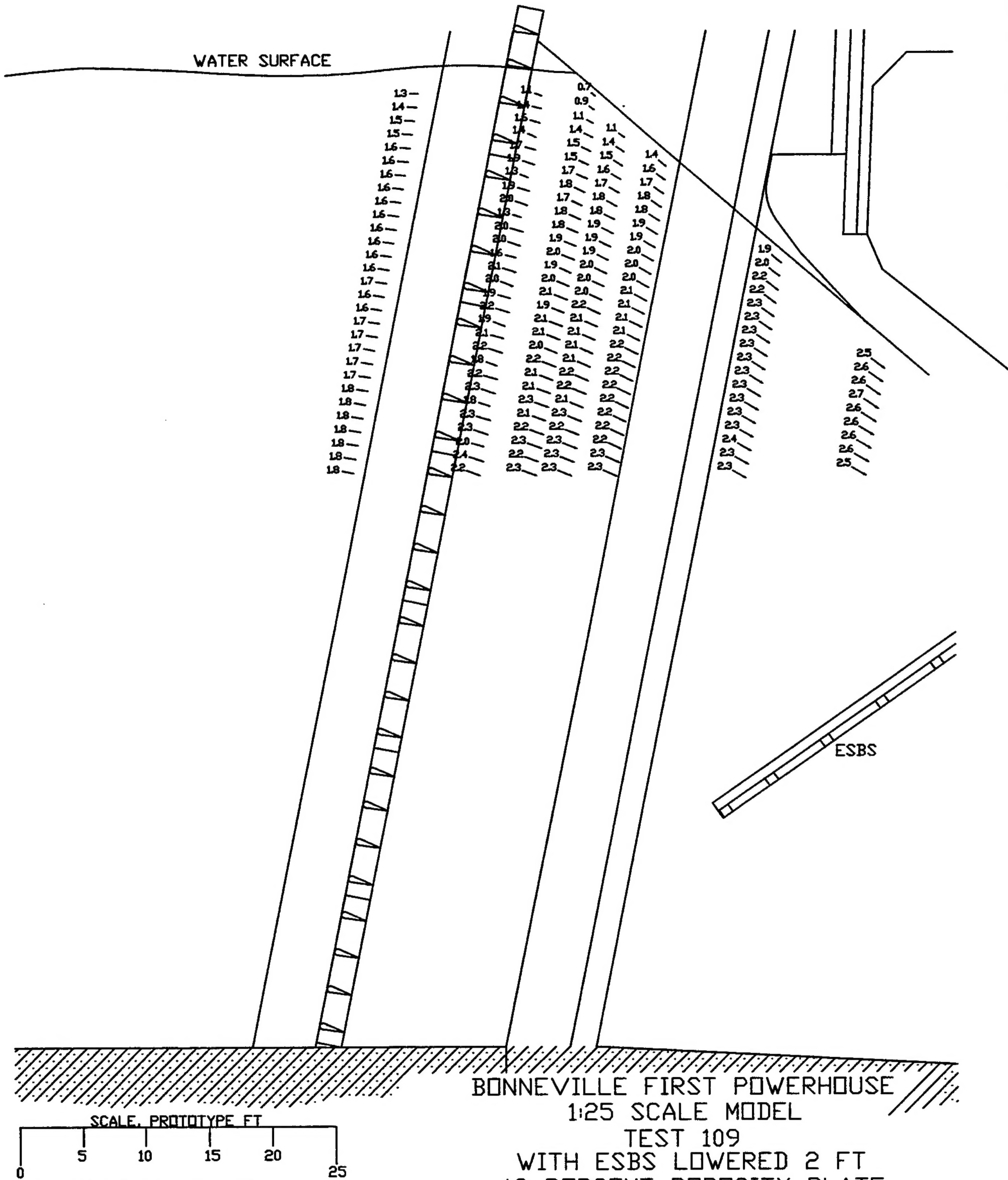


SCALE, PROTOTYPE FT

0 5 10 15 20 25

VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST108.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 108
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
20 FT PIER EXTENSION
TRASHRACK MEMBERS ANGLED @ 5.1 DEG
ROOF EXTENSION #2



VELOCITIES PLOTTED IN FT/S
ELEVATION VIEW
BTEST109.DWG

BONNEVILLE FIRST POWERHOUSE
1:25 SCALE MODEL
TEST 109
WITH ESBS LOWERED 2 FT
48 PERCENT POROSITY PLATE
Q = 11,300 CFS
FOREBAY EL = 74.5
BAY C AVE VEL
20 FT PIER EXTENSION
TRASHRACK MEMBERS ANGLED @ 5.1 DEG
ROOF EXTENSION #1

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Hydraulic Model Investigation

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Robert Davidson

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

Bonneville dam is located on the Columbia River at river mile 146.1, approximately 40 miles east of Portland, OR (Figure 1). It is a multipurpose project that consists of the first and second powerhouses. The old and new navigation locks and a 1,600,000-cfs capacity spillway. Construction of the first powerhouse, the old navigation lock, and spillway began in 1933. President Franklin D. Roosevelt dedicated the lock and dam on September 28, 1937. The construction of the first powerhouse was completed in 1943. The first powerhouse has a flow capacity of approximately 128,000 cfs and a rated power output of 526,700 kw. Construction of the second powerhouse began in 1974 and was completed in 1981. The second powerhouse has a flow capacity of approximately 160,000 cfs and a rated power output of 558,200 kw.

The main purpose of this study is to identify modifications to the Bonneville First Powerhouse Fish Guidance System that will improve survival of juvenile salmon passing Bonneville Dam.

15. SUBJECT TERMS

Bypass screens
Extended bar screen
Fish guidance system
Powerhouse
Streamlined trash racks

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
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